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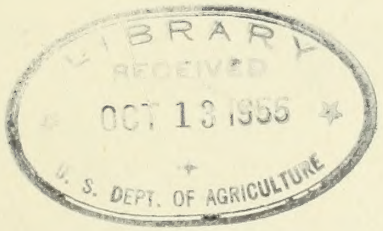
PROCEEDINGS OF THE THIRD SOUTHERN CONFERENCE ON FOREST TREE IMPROVEMENT

Held at

New Orleans, Louisiana,

January 5 and 6, 1955



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SOUTHERN FOREST EXPERIMENT STATION
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE

May 1955

ABOUT THE THIRD SOUTHERN CONFERENCE

Through the courtesy and cooperation of Newcomb College and Tulane University, New Orleans, Louisiana, the Third Southern Conference on Forest Tree Improvement was held in the Recreation Room of Dixon Hall, Newcomb College. Private dining space at noon on both days of the Conference was provided at Bruff Commons, Tulane University.

Like the First and Second Conferences at Atlanta in 1951 and 1953, the Third Southern Conference was sponsored by the Committee on Southern Forest Tree Improvement. In contrast to the First and Second Conferences, which dealt primarily with problems, plans, and the initiation of programs, the Third Conference stressed accomplishments in forest tree improvement in the South.

Officers of the Committee on Southern Forest Tree Improvement at the time of the Third Southern Conference were:

Clemens M. Kaufman, School of Forestry, University of Florida, Chairman

E. G. Wiesehuegel, Division of Forestry Relations, Tennessee Valley Authority, Vice-Chairman

T. E. Bercaw, Forestry Department, Gaylord Container Corporation, Secretary

The Program Committee consisted of:

D. A. Anderson, Texas Forest Service, Chairman

George I. Garin, Department of Forestry, Alabama Polytechnic Institute

Philip C. Wakeley, Southern Forest Experiment Station, Forest Service, U. S. Department of Agriculture

The Committee on Local Arrangements consisted of:

Philip A. Briegleb, Director, Southern Forest Experiment Station, Forest Service, U. S. Department of Agriculture, Chairman

Willis A. Eggler, Department of Botany, Newcomb College

Philip C. Wakeley, Southern Forest Experiment Station, Forest Service, U. S. Department of Agriculture

This is the twelfth technical paper released under the sponsorship of the Committee on Southern Forest Tree Improvement. A list of all previously sponsored papers is given on page 132, following the list of individuals who registered at the Conference.

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PROCEEDINGS OF THE THIRD SOUTHERN CONFERENCE ON FOREST TREE IMPROVEMENT

New Orleans, Louisiana, January 5 and 6, 1955

Morning Session, January 5
Moderator, E. L. Demmon

1. OPENING REMARKS

E. L. Demmon, Director
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Forest Service, U. S. Department of Agriculture

It is a pleasure to act as Moderator at this opening session of your conference on forest tree improvement. Not only is it a pleasure to be back amongst friends in New Orleans where I spent so many years of professional work (1925-1944), but also to have a small part in this important discussion of forest genetics.

My interest in forest genetics dates back about 35 years to the time when I helped initiate breeding experiments with plantation rubber in the East Indies, to increase yields of natural rubber. That experiment grew into practices which resulted in greatly stepping up average yields by the American company with which I was associated.

During my tenure at the Southern Station, studies by Wakeley and others were initiated to determine the effect of geographic source of seed, and to increase yields of gum naval stores through seed selection. These studies are now bearing fruit, and have served as background for further research. Also, our Southeastern Station is now well launched in forest genetics work in Georgia and Florida, the results of which will be reported at this conference. I am glad to see that the Lake States Forest Experiment Station is represented on the program, as I was also connected with that station for several years (1944-1951).

Back in April 1938 I gave a talk on "The Importance of Forest Genetics Investigations in the South" before a Farm Chemurgic group in Chicago. In that discussion I stressed the need for stepping up research

in forest genetics, but progress has been very slow until recently. I am sure it is stimulating to all of us to know that a Southern Institute of Forest Genetics, from which we can expect important contributions, is now a reality.

Many groups and institutions throughout the United States are at present busily engaged in forest tree improvement research. It is a fine thing to hold periodic conferences such as this, to hear reports on progress being made, and to better correlate research efforts, thus avoiding unnecessary duplication. I congratulate your Committee on having arranged such an excellent program.

And now I have the pleasure of introducing your first speaker, a man who is well known to all of you, and who is an authority on his subject, "The Place of Forest Genetics in Silviculture"--Dr. Scott Pauley of Harvard University.

2. THE PLACE OF FOREST GENETICS IN SILVICULTURE

Scott S. Pauley
Maria Moors Cabot Foundation, Harvard University,
Petersham, Mass.

Several years ago a graduate student in silviculture whom I knew showed me a chart he had made. The exact title of the chart I cannot now remember, but it seems to me it was labeled "The Tools of the Silviculturist", or perhaps "The Factors Influencing Tree Growth and Development". The purpose of the chart was not simply to list the "silvicultural tools" or to enumerate the factors involved in the growth and development of a tree, but to show how they were interrelated and how they interacted. The chart was done, I might point out, on a rather grand scale--about 5 x 5 feet actually--and demonstrated that much thought and effort had been expended on it.

I remember that top center--the usual place of honor in such compositions--was given over to the photosynthetic reaction. Radiating downward were a series of principal arrows which established contact with the sun, carbon dioxide, and water. And these, in turn, were connected and interconnected with the soil, the atmosphere, the wild flora and fauna of the forest, man, and, indeed, almost everything. I remember I was particularly interested to note that the frass extruded from wood borers' or bark beetles' tunnels was connected, rather tenuously, to the soil; which, of course, indicated quite rightly that one should not neglect to recognize that even a lowly Dendroctonous may increase the organic increment of the soil, and thus possess some virtue as a silvicultural tool.

As a geneticist, I was naturally interested to know what role as silvicultural tools was given to the genes of the organisms involved in this scheme of things. I studied the chart in considerable detail--all 25 square feet of it--but I regret to say that tree genes (or even the genes of the bark beetles) had not, evidently, qualified for inclusion.

Such a concept of a geneless forest, as symbolized by this student of silviculture, was by no means unique or uncommon a few years ago. In fact, it has been only within very recent years that most forest biologists have come seriously to recognize that trees do, indeed, possess genes, and that they are, in consequence, subject to the same genetic laws that have been observed to govern heredity and variation in other organisms.

The situation that existed before what we might call "the rise of forest genetics" was not, in reality, quite as primitive as I have described. The fact is that foresters have always been keenly aware of genetic diversity at the species level, and were not unaware even that it existed in many species below this level. The important practical and theoretical contributions that forest genetics is capable of making in forestry are not, therefore, in a strict sense, particularly new or revolutionary. A recognition of genetics has tended simply to focus the attention of the forest biologist on the individual tree, rather than the species, and has made him more acutely aware of the basic biological concept that each tree in the woods is the end product of a continuous interaction between its genotype and the environment in which it has grown.

The committee responsible for organizing the program for this third Southern Forest Tree Improvement Conference has, I presume, felt that it might be wise to define again the role or place of genetics in silviculture.

By now, I think, most forest biologists are in general agreement that forest genetics includes that field of inquiry concerned with the study of heredity and variation in forest trees. Like "corn genetics", or "wheat genetics", or "Drosophila genetics", forest genetics is concerned with a special group of organisms, and is thus merely a specific area of investigation in the broader field of the mother science, genetics.

In this connection I think it may be worth-while to reemphasize that forest genetics is strictly a fundamental, rather than an applied, science. It is thus exclusively a research field concerned with the elucidation of basic biological problems, and makes no effort to evaluate such facts in terms of their possible utilitarian value. Application of facts derived from forest genetic research is the concern of the silviculturist or the tree breeder.

I am not, of course, so naive as to believe that investigators in forest genetics must keep their minds and hearts unsullied by economic considerations. Indeed, most of the current research in forest genetics, here and abroad, is admittedly designed to produce data of practical usefulness. If the research were not so designed, I am sure you would all agree that financial support, regardless of source, would be considerably curtailed.

If we must find a "place" for forest genetics, it seems to me quite clear that it is a part of silvics, i.e., that group of basic sciences upon which silviculture, theoretically, is based.

My impression is that the niche or place of forest genetics is now fairly well established, and that most forest biologists are pretty well reconciled to the fact. There are some environmentalist strongholds that still persist, of course; but these are few and unimportant. I am convinced that the pioneering work that has been done in the modernization of silvicultural thought by the Southern Forest Tree Improvement Committee and those committees in other regions will not soon fade away. Even those citadels of conservatism--our forestry schools--have, at long last, begun to realize that the concept of a geneless forest has, in the middle of the Twentieth Century, a dated look.

If graduate students in silviculture continue in the future to fashion charts depicting "the factors influencing tree growth and development", I have the feeling that in an important place on such charts, very likely near the top, will be found the word "genes".

3. TREE RACES AND FOREST TREE IMPROVEMENT

Paul O. Rudolf, Forester
Lake States Forest Experiment Station, St. Paul, Minn.[1/]
Forest Service, U. S. Department of Agriculture

The general aim of forest tree improvement work is to discover and develop better forest trees. Basic to such work is a knowledge of the hereditary or genotypic variation within forest tree species.

Doubtless the first forester noted variation between trees of the same species. For a long time, however, it was assumed that such differences reflected chiefly tree age and environment. Probably the first published inference that individual tree variation might be hereditary was by Richard Brandley in England in 1717 (3). He Recommended that seed be obtained from trees which combined high yield and other desirable characters. An anonymous Swedish author in 1769 correctly interpreted the deformities of some planted trees as resulting from unsuitable seed (1). The first actual demonstration of racial variation was initiated in France in 1820 by de Vilmorin (10). He planted Scotch pine (Pinus sylvestris L.) of 10 different seed origins over a period of years and some 20 to 40 years later described three types or races among these plantings.

1/ Maintained in cooperation with the University of Minnesota.

What We Know About Racial Variation

Despite de Vilmorin's pioneer study, foresters paid little attention to seed origin until the early 1900's when the bad effects of the wholesale planting of Scotch pines grown from cheap seed (usually of poor sources) became evident in Europe. Since then a number of studies have been made and experimental evidence of racial variation has been accumulated for about 25 North American tree species and some 20 foreign species (8). There is good observational evidence of such variation in about 20 more forest tree species. Altogether these include Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), ponderosa pine (Pinus ponderosa Laws.), the southern pines, eastern white pine (P. strobus L.), red pine (P. resinosa Ait.), jack pine (P. banksiana Lamb.), and most of the commercially important forest trees of North America and Europe.

The forest tree species, like any biological species, is merely a group of individuals with a certain number of characters in common and reproductively isolated from other related groups. If the species grows over a geographic or altitudinal range containing a wide variety of conditions there probably will be great variation within it. If distribution is continuous over the range there probably will be gradual, or clinal, differentiation in characters. In such instances, races may represent merely samples of a continuously varying genetical population. On the other hand, where natural barriers break up the species into more or less isolated segments, variation may be sharp within relatively small distances. The southern pines probably represent well the first type of continuous, or clinal, variation. Ponderosa pine and quaking aspen (Populus tremuloides Michx.), on the other hand, represent both types of variation.

Most of the seed source studies made so far have been somewhat exploratory in nature. As Wakeley has said, "They have not been attempts to improve trees, but merely to preserve the status quo in terms of hardiness, growth rate, and the like" (11). How many races[1/] there are and their approximate delimitations have been worked out partially and somewhat tentatively for only about five American species--Douglas-fir, loblolly pine (Pinus taeda L.), ponderosa pine, red pine, and white ash (Fraxinus americana L.).

However, some more comprehensive studies have been made. For example, the Lake States Forest Experiment Station in 1933 field-planted red pines of 154 seed sources. About 10 years later Wright, in the Northeast, studied the 2-year-old progeny of 155 parental sources of white ash (12). More recently a number of new studies have been initiated. The most comprehensive ones yet undertaken are the southern pine seed source studies sponsored by the Southern Forest Tree Improvement Committee. We need much more research of that scope to help clarify the pattern of variation among our important forest tree species.

1/ The term "race" is used here in a broad sense, essentially equivalent to ecotype. Many modifying adjectives have been used with the term race (geographic, altitudinal, climatic, local) but they are not very precisely defined.

Races As A Basis For Tree Improvement

The primary object of forest tree improvement usually is to develop trees which combine large size, relatively rapid growth, desirable form and branching habit, and good quality wood. Unless such trees are hardy in the locality in which they are to be grown, however, possession of these valuable characters will be of little importance.

This is where racial variation enters the picture. Local races, which have developed over centuries in place, are well adapted to the climatic extremes and the biotic enemies native to the locality. It might be assumed, therefore, that the best procedure would be to base improvement practices on the best trees of the native race. In many instances this may be the best practice, but we still have to know the distribution of the native race. Where variation is discontinuous, delineation of the native race may be easy, but where variation is continuous, arbitrary, but soundly based, racial boundaries will have to be drawn.

However, the solution is not so simple as this. Certain races of some tree species have proved better than local races in some localities. For example: (1) The East Baltic race of Scotch pine produces a better tree than local races in a number of German localities, (2) Norway spruce(Picea abies (L.) Karst.) from certain German sources develops better trees in southern Sweden than do local races, (3) the Burmese race of teak (Tectona grandis L.) produces better trees than do local races in some parts of India, (4) Douglas-fir from the Palmer area in northern Oregon out-performs local Douglas-fir at Wind River, Washington, and (5) ponderosa pine from the Lolo Mountains in Montana yields more wood than do local sources in northern Idaho. The same may well be true of many other trees, so there should be a thorough search for superior races among all our important forest tree species. Furthermore, insects and other biotic enemies sometimes are introduced into new areas and may find the local races highly susceptible hosts. In such instances other races may be more resistant to damage. The obvious conclusion is that comprehensive research into racial variation is of great importance.

Illustrating The Point

Such eminent researchers as Baldwin, Duffield, Pauley, Perry, Righter, Wakeley, and Zobel have stressed the importance of seed source tests as a basis for tree improvement work (2, 5, 6, 7, 11, 14). Perhaps this point can best be illustrated by a few examples:

1. The study of loblolly pine established at Bogalusa, Louisiana, in 1925, showed that moving seed in from a lower temperature zone only 350 to 400 miles northwest or northeast reduced pulpwood production over the next 22 years by about 60 percent. Differences in disease resistance between sources were notable.

2. A study of red pine seed sources in the Lake States showed that at age 18 (years from seed) trees from the home locality (northeastern Minnesota) on the average had produced more total cubic-foot volume than those from any other locality, nearly three times as much as that from the poorest region. However, seven sources from the home locality varied more widely in volume per acre than did the regional averages. The best of the local sources had produced about seven times as much wood as the poorest one. Some sources from other seed collection regions had produced more wood than some local sources. These findings point out the need not only for delimiting geographic races, but also for discovering local races.

3. In a study of black walnut (Juglans nigra L.), Wright found evidence of three broad geographic races but with considerable variation in juvenile growth rate within them. He concluded: "Further work will be needed to show whether the races are moderately distinct or merely portions of clines; and whether there are local races within the broad geographic races or the local variation is merely random" (13).

4. Recently Duffield made this statement: "Some results of the pine crossings made at the Institute of Forest Genetics, as well as birch and aspen crossings by the Cabot Foundation, show that the performance of species hybrids is greatly influenced by the racial origin of the parents. Western white pine of western Washington origin produces much faster growing hybrids when crossed with eastern white pine than does western white pine of Sierra Nevada origin. The species hybridizer cannot escape the provenance problem" (5). Had more races been available for both parent species, it is possible that even a greater variety of results might have been obtained. Similarly, Righter, in speaking of exploratory hybridization of pines said: "The next step is to develop improved forms of the hybrids through genotypic selection of the parental stocks within the proper proveniences" (7).

5. Photoperiodic growth response must also be recognized as one of the genetically controlled reactions important in racial diversity (6, 9). Pauley and Perry, in discussing the significance of results of their comprehensive study of the photoperiodic response in Populus said this: "Theoretically, by the initial use of parental ecotypes which give reactions approaching the extremes in day-length response, an F_2 will result which may be expected to contain gene combinations adaptable to almost any growing season length at any latitude" (6).

A Suggested Procedure

Accepting the fact that a knowledge of racial variation is a necessary basis for tree improvement work, it is evident that a great many more seed source or provenience studies are needed. Not only must such studies be made for all the important forest tree species, but also they must be localized so as to cover the range of growing

conditions (site as well as climatic conditions) in which the species is to be used. Except for the southern pine studies none of those yet established appear to approach this intensity.

Much of the possible improvement of forest trees, however, depends upon the recognition and utilization of individual tree variations. Logically such selection could be the second step--after tree races have been delimited. To avoid the prospective long delay, however, both racial and individual tree studies can be carried on concomitantly. A number of individual tree collections can be used to represent various localities. Wright has suggested such a procedure based on his considerable experience with seed source tests (13). To avoid great expansion of the size of test plantations, only a small number of trees per source would be used in each planting. This would provide a basis somewhat poor for determining survival but adequate for assessing growth and development of individual parent progenies. Of course, there ought still to be a network of plantations containing enough trees of each source in blocks to indicate their development under stand conditions.

The forest tree breeder does not have available to him the highly improved lines that the agricultural plant breeder has. Yet he too should use the best material available to reduce the work of eliminating undesirable genes. His best chance for obtaining desirable germ plasm probably is from locally adapted races. Stands on average sites probably will provide a greater diversity of germ plasm than those on either good or poor sites.

Some other aspects of tree breeding also are dependent on a knowledge of tree races. For example, Wakeley has suggested the possibility that hybrids between geographic races within a species may be adapted to a wider range of environments than either parent race (11). I might add the possibility that they may be adapted to environments different from those of either parent race. There is also the possibility that inter-racial hybrids may be more vigorous than either parent. Such a situation was demonstrated for Scotch pine by Dengler in Germany in the 1930's (4). The breeder too, can make some progress prior to the delimitation of geographic or local races by utilizing the most desirable trees in stands growing within homogeneous climatic zones. He recognizes, of course, that the pattern of racial development probably will differ from species to species, even among those having similar distribution. Nevertheless, useful progress can be made at the risk of some mistakes, without decades of delay.

Conclusion

I think there is no more fitting conclusion to this paper than to quote once more from Phil Wakeley. Recently he said this: "The inescapable conclusion is that selections and hybrids must be made separately, region by region, within the framework of existing geographic races. To the extent that this is true, provenance studies designed to identify such races and define their territorial boundaries

are fundamental to other phases of tree improvement" (11). I would modify this statement to this extent only: I would not limit it to geographic races, and I would point out that the studies of racial variation, selection, and breeding, although interdependent, can be carried out more or less simultaneously.

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4. SET-BACKS AND ADVANCES IN THE SOUTHWIDE PINE SEED SOURCE STUDY

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Forest Service, U. S. Department of Agriculture

The Southwide Pine Seed Source Study probably is familiar to most of you from a number of published notes concerning it, and certainly needs no introduction to those of you cooperating in its execution. It is for these reasons, as well as to conserve the time of the Conference, that the Program Committee has asked me to report mainly on the gains and losses experienced in bringing the study through its first three years. These gains and losses can as yet be evaluated only in rather general terms, but can, I hope, be made more vivid to you by means of a few slides.

At least four other provenance tests of southern pine seed were begun before the present Southwide Pine Seed Source Study was launched in 1951. The present study, however, was the first specifically designed to permit mapping, for loblolly, slash, longleaf, and shortleaf pines, the zones within which seed may be moved freely from collecting ground to planting site, but across the boundaries of which seed probably or definitely should not be moved.

The present study is a tremendous undertaking. It has involved collection of seed from 50 geographically distinct sources, and production and shipment of 1,824 lots of stock from 19 different nurseries and their establishment in 66 separate plantations in 16 different States. Planting, by the end of the current season will total, in

1/ Chairman of the Subcommittee on Geographic Source of Seed, Committee on Southern Forest Tree Improvement.

round numbers, 220,000 trees. All seed collection, stock production, and planting has been carried out by volunteer cooperators--several hundred of them in dozens of different organizations. Coordination of the work has been effected entirely by mail and an occasional telegram or long-distance telephone call. In an enterprise as vast and farflung as this, some set-backs have been unavoidable. What these set-backs have been, and to what extent they may have jeopardized the purpose of the study, is the main subject of this paper.

1. Shortage of 1951 seed in some localities, and failure to find cooperators in others, led to a few omissions of desirable sources from the study, and an occasional less-than-optimum grouping of sources in test plantations. In addition, a very few seed lots were collected in an off-standard manner. The Subcommittee on Geographic Source of Seed feel that these set-backs are minor and have not materially weakened the study.

2. Other shortages in 1951 and 1952 necessitated planting one of three longleaf pine "series" a year later than the other two. They also necessitated planting adjacent plots in the one slash pine series and in two longleaf series in two successive years instead of simultaneously. This mixing of age classes has complicated establishment records and re-examination schedules. It has robbed initial survival of part of its value for distinguishing geographic races, and it may reduce the value of some pathological data. It is thought, however, that the mixed age classes will have unimportant effects upon growth to pulpwood size and beyond.

3. In 1952, about a third of the cooperating nurseries produced insufficient stock from one or several seed lots. Practically all shortages were made good from surpluses at other nurseries, but at the cost of further complicating establishment records and further decreasing the value of initial survival as a measure of racial variation. As in the case of mixed age classes, however, the harmful effects on the more important long-time phases of the study should be relatively unimportant.

4. One of the most feared sources of trouble--departure from prescribed design in planting--proved least important. Of the 1,528 plots put in in 1952-53, 94 percent were perfectly installed, and an additional 4 percent well enough installed to meet the needs of the study. So far as is known, all 260 plots planted in 1953-54 were perfectly installed, and the 36 plots remaining to be planted should cause little or no trouble. Of the 1,788 bundles of 121 trees each that have been lifted and shipped to date, only 1 has been lost in the shuffle--truly a remarkable record.

5. Mortality--especially from drought--in 1952 and 1953 has set the study back more seriously than all other mishaps combined. Up-to-the-minute details are unavailable, because only part of the plantations have been scheduled for reexamination this winter, and the scheduled re-examinations are not yet complete. From all available information,

however, the current state of the study appears to be as follows:

> Of the total of 66 plantations, 9 apparently have suffered such heavy mortality as to be valueless or nearly so, and an additional 25, while still capable of yielding useful information, may be less subject to precise evaluation than had been hoped. The remaining 32 plantations should permit rigorous, sensitive statistical analysis as originally planned.
>
> The worst losses have occurred in the western-most part of the territory covered by the study, and in the Carolinas, and shortleaf and longleaf pine plantations have suffered most severely. As a result, there is some question whether seed-collecting zones for these two species can be mapped satisfactorily without the establishment of additional plantations. The feasibility of such additional planting of longleaf and shortleaf has not yet been fully explored.
>
> This is the debit side of the ledger.

On the credit side, useful mapping of loblolly and slash pine seed-collecting zones seems assured from plantations already in the ground. In addition, the longleaf and shortleaf plantations which have survived initial establishment constitute a reservoir of information not to be ignored. Any one such plantation, because of superior design and better choice of seed source, is potentially more valuable than the original loblolly seed source plantation established at Bogalusa with seed from the 1925 crop, which will be reported upon by Bercaw later this morning. Any pair of such plantations of the same species and series is far more valuable than the original one at Bogalusa because it measures the interaction between an array of genetically different stocks and two distinctly different geographic settings. The inroads of drought, therefore, have by no means robbed the longleaf and shortleaf components of the study of all usefulness, even though they have rendered them inferior to the loblolly and slash pine portions of the study.

Also on the credit side must be recorded the rapidly accumulating evidence that the geographic sources under investigation do, in many instances, represent different races of the four principal southern pines. Differences in growth rate, in foliage habit, in root habit, and in reaction to day length and to low temperature appeared in the nursery during the first year. The first and second years in the field have brought out some differences in survival which can be attributed only to racial variation, and numerous racial differences in growth rate, cold resistance, and resistance to heat and drought. In loblolly pine differential infection by fusiform rust, to be reported in more detail by Henry, has confirmed, and may have usefully extended, the findings in earlier studies of rust infection in this species. Considerable time must still elapse before the pattern of these various differences is clear enough for economic application. Nevertheless it is decidedly

encouraging to have so much of the pattern show within three years of the collection of the first seed used in the study.

5. STUDY OF SEED SOURCE IN REVERSE

Sulo Sihvonen, Manager
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The Crossett Company started its program of tree improvement in 1922 when it was decided to cut the virgin forests to a seed tree basis. The logging boss in those days was a farseeing man in that he felt that only the best trees should be left for seed. This was perhaps best exemplified by a visit paid to his operations by one of the Board of Directors and the late Austin Carey. Both of the latter felt, and expressed themselves, that the monetary loss by leaving the best trees was too great when most any old tree would do the job of seeding just as well. The logging boss was somewhat startled but never batted an eye in replying that he couldn't see why the best trees shouldn't be left for seed when even the sorriest farmer wouldn't permit a runt bull to run with his herd. Needless to say, he won his point and Crossett has benefited by the regeneration of a new forest from good parent trees.

Through the intervening years, starting in 1934, Crossett's raw material production from its own lands has come from selection cutting and thinnings. Since most of this cutting has been of an improvement nature, the quality of the stands with respect to tree form and vigor has improved considerably through the years.

Because we feel that our forest has a head start with respect to potential production of high quality seed, we were pleased to consider a test to determine how good our seed is within a reasonable distance of Crossett.

The progress of the broad southwide study on geographic sources of seed has just been reviewed for us. As has been pointed out, this project has for its objective the determination of provenance boundaries for the four major southern pines beyond which it is not desirable to import seed for planting. Because of the broad scope of the study, however, the results may only apply in a very general way in specific localities. Therefore, local seed source tests in which local seed is checked against that from outlying areas are necessary to fill in the gaps left by the broader, parent study.

Both the over-all study and the local supplements to it have considerable practical significance. We now find it profitable to use all of a pine tree with the exception of its branches. Why not

extend this into the branches and use the good cone crops when they occur? If one can prove that his local pine has genetic characteristics making it superior or at least equal to a given local source in its own area, the possibility of harvesting and marketing seed as well as lumber, pulpwood, or poles has interesting possibilities.

One's first reaction is that collection and handling of seed is such a tedious procedure that it would be difficult to make any real showing or profit. It has largely been a slow procedure in the past because most of us have not made any provisions in our normal operations to expedite seed production. The research which has been done in seed stimulation and in the management of seed orchards or seed producing areas, about which we will hear during this session, points the way to how we can do this and successfully integrate it with our other operations.

The periodicity of seed crops is a factor with which we all must contend. In our Crossett area, the nine-year post-war period has given us one excellent seed year, one very good, three fair, and four failures. The good or better years have been four years apart and there seems to be a tendency for failures to occur two years at a time. Of course, heavy collection in good years and adequate storage is one way to get around the variable supply. Storage presents some problems, however, and one cannot always anticipate just what his needs are going to be. A reliable source from somewhere besides one's own territory would be extremely useful at frequent intervals. It is not too clear just how local in nature seed failure is in given years. If it proves to generally cover rather large areas of several states at a time, the investigation of seed source differences within this area becomes of less practical importance. There is considerable reason to think, however, that failure is often much more local in nature, making the filling in of gaps in the broad southwide study much more useful.

The foregoing comments are primarily further justification of the value of not only the local seed source tests, but the parent study of geographic sources of seed as well. Current forestry practice no longer allows us to wait indefinitely for nature to do the seeding. The future points toward a situation of even greater intolerance toward leaving forest land partly idle for even a few years.

Local seed source studies can take varying forms. In the Crossett seed source study we are interested in exploring the possibility that seed collected in the Crossett area can be used to advantage in adjacent states and localities in place of their local seed. This type of study has been referred to as "a seed source study in reverse". This is in contrast to the normal type of study in which seed from a number of outlying areas is tested along with a local source. Such checks are being made, however, with many of them integrated with the Crossett study. The objectives of the Crossett study are two-fold: (1) to certify Crossett seed and seedling stock as equal to or perhaps superior to local seed within carefully defined

areas, and (2) to locate seed source provenances which are as satisfactory in our Crossett area, or nearly so, as our local source.

At present, the study is limited to loblolly pine. Seed collected in the Crossett area has been sent to cooperators in neighboring states to be raised with seed collected in those areas. The cooperation of over 20 persons representing 12 organizations in five states has been obtained. The standardized working plan for local tests of seed source prepared by the subcommittee on Geographic Source of Seed under the direction of Phil Wakeley has been used as the guide. The Crossett Research Center of the Southern Forest Experiment Station not only conceived the study, but is also coordinating the program.

Approximately ten pounds of seed collected in the Crossett area in the fall of 1951 was distributed to cooperators and sown in eleven different nurseries in the spring of 1953. Nursery survival and growth rate were generally satisfactory, and the seedlings were lifted and outplanted in the winter of 1953-54. The number of seed sources planted by each cooperator varied from two to eight. However, although the comparison of Crossett seed with the local source was necessary for the Crossett seed source test, the others helped to supplement the over-all geographic sources of seed study. Acceptable designs for planting following the outline given in the working plan were drawn up for each plantation. All cooperators followed the designs faithfully, thus making the job of analysis relatively easy. Each cooperator was supplied with instructions and materials to help in establishing and recording information on the plantations. These included a record of establishment, a map of the plantation site, a design for location of each seed source in each block, planting instructions, and height measurement forms for the planted seedlings.

A total of 14 plantations, involving 268 seed source plots in 64 randomized blocks were set out by cooperators in the winter of 1953-54. Five of the cooperators set out two plantations, either in different parts of the state or on a different site within the same general area. Most of the plots are located in south Arkansas or in Louisiana, but some are located as far north and east as Tennessee and northwest Alabama, and one is in east Texas. One plantation has been deferred and will be set out this winter in southwest Arkansas.

The plantations have now been in for one year. This was a severe season, characterized by blistering heat waves and severe drought. Thus, it is not surprising that many of the plantations were lost. It is still too early in the life of this test to take much stock of the results obtained. Plantation survival and measurement forms were sent to cooperators in November, however, and although returns are not complete at this time, the results as we have them can be pointed out.

Survival of five of the fourteen plantations is definitely known to be complete or almost complete failures. These include the one in east Texas, one in west Louisiana, two in north Louisiana, and the local

plantation at Crossett. All of these should be replanted. Three plantations in south Louisiana and one in north Louisiana show fair to good survival and can be used in further analysis. The south Mississippi plantation shows fair survival, but the one in north Mississippi is reported to be largely gone. The fate of the others is not yet reported.

Detailed results are not far enough along to draw any conclusions. Survival on two plantations in central Louisiana shows one case of Crossett stock having 56 percent survival as compared to local stock at 40 percent, and in the other 69 percent to 53 percent in favor of Crossett as compared to local stock. In a southeast Louisiana plantation the comparison was 83 percent for the Crossett seed stock to 77 percent for the local. In north Louisiana a failed plantation showed 17 percent for the Crossett source, 13 percent for the local. The plantation at Crossett had a survival of 41 percent with Crossett seed stock and 22 percent, in comparison, with stock from a Mississippi source. Thus, so far, the Crossett stock seems to do quite well in survival comparisons with other sources.

Though data on the height of the seedlings when planted was not requested, many cooperators volunteered this information. In general, the Crossett stock was somewhat smaller than local stock at the time of outplanting, particularly for the south Louisiana plantations. This could have been a significant factor in the survival trend just quoted. First year remeasurement figures are available only for the Franklinton plantation in central Louisiana. There the local stock is growing slightly better than Crossett stock.

It is intended to have as many of the failed plantations replanted as possible, although all may not be accomplished this year. It would also be desirable to extend the study to include eastern Oklahoma and possibly one or more eastern states if cooperators can be found. The undesirable weather cycle for plantation survival, that we seem to be in, is unfortunately delaying the progress of this test, but we hope to see trends and conclusions drawn as soon as possible.

6. FIVE YEAR RESULTS OF LOBLOLLY PINE GEOGRAPHIC SEED SOURCE TESTS

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Foresters have long been interested in extending the use of rapid growing southern pines northward as a means of achieving increased growth in volume and quality. They have also been interested in seeking within the range of loblolly pine those races which would achieve similar objectives. Little information was available on this subject when Tennessee

Valley Authority in 1950 decided to experiment with some of the many seedlots planted in its nurseries from widely separated collection points. It seemed like a good opportunity to initiate tests that would provide more specific information on significant variations of plantings of different seed sources in different locations and in the same location.

The test is fully described in the Appendix of TVA Technical Note 14, which was developed as a project of the Southern Forest Tree Improvement Committee on Testing Tree Progeny (4). Essentially, the plan called for testing nine seed sources at eight locations, ranging from central Alabama to Illinois and from Arkansas to the South Carolina Piedmont, as shown in Figure 1. Three blocks were established in each locality, representing complete replications. Within each block, seedlings from the various sources were assigned at random to nine plots.

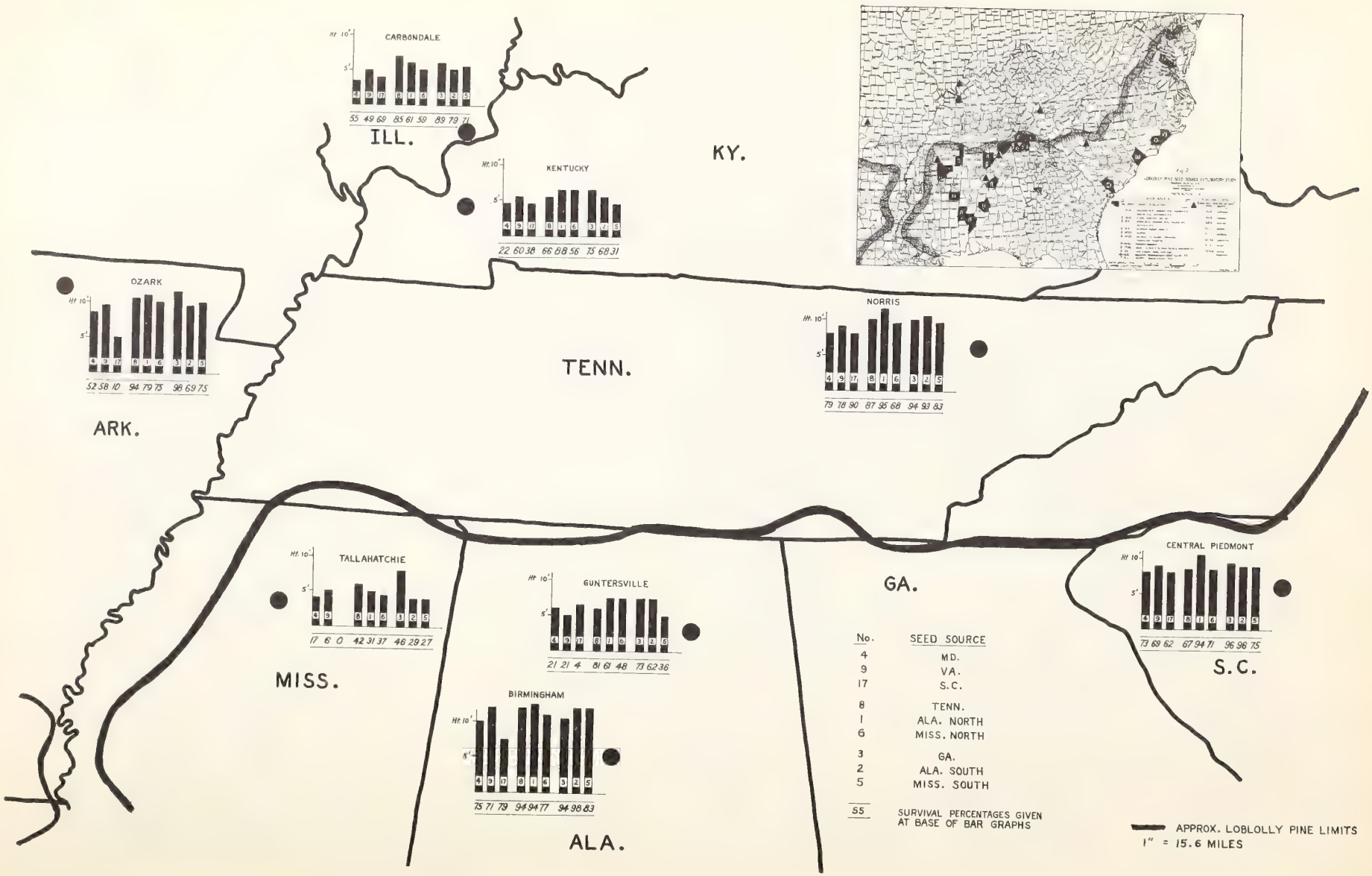
A project as extensive as this one required a great deal of cooperation. And for that cooperation, recognition and thanks are due to the members of the Central States Forest Experiment Station at the Carbondale Research Center, the Southern Forest Experiment Station at the Ozark, Tallahatchie and Birmingham Research Centers, the Southeastern Forest Experiment Station at the Central Piedmont Research Center, and to cooperating divisions of the Tennessee Valley Authority at Guntersville, Alabama, and Paris, Tennessee, and last but not least, to Mr. W. H. Cummings, who organized and helped establish the investigation. With the assistance of the above, experimental plots were established at the eight localities shown, in Illinois, Arkansas, South Carolina, Alabama and Mississippi. TVA established three in Tennessee, Kentucky and Alabama. Four of these locations lie outside the natural range of loblolly pine and four inside. The seed sources are equally divided among the Atlantic Coastal Plain, the north fringe of the loblolly pine type, and southern sources.

At the end of the second year results began to appear and were published in the Journal of Forestry (3). Seedlings from the North Carolina seed source failed generally the first year. They were replaced with new seedlings from a South Carolina source and these failed. A third South Carolina source gave mediocre success, as will be discussed later. Two year height growth showed Alabama trees best and those from Maryland and Virginia sources poorest, on the average.

We are now in a position to begin an evaluation of the fifth-year results of this study. Although no disasters have hit any of the plots, all but one of the three replications in the Tallahatchie plantings in Mississippi were lost because of the extremely dry weather. Pine tip moth damage has occurred on most of the plantings but has not been evaluated as to seed source and location. The measurements reported here were taken in October and November 1954 and represent an up-to-date analysis of the survival and height growth of the various seed sources in the eight localities.

Fig. 1

TVA SEED SOURCE STUDY



The average survival by seed sources is shown in Table 1, and by planting locations in Table 2. Only the Atlantic Coastal Plain seed sources ran lower than the overall average survival of 57 percent. The difference is significant and is reinforced by the complete failure of two selections from the Coastal Plain of North and South Carolina. Survival from seed originating outside the Coastal Plain averaged 71 percent as compared with 49 percent for the Atlantic Coastal Plain seed. Thus it would seem that from the standpoint of survival the inland sources are one and one-half times better than the Coastal Plain seed sources.

If the unusual situation caused by the drouth in Mississippi is disregarded, there is little difference in average survival between plantings inside and outside the natural range of loblolly pine. Insofar as these studies are concerned, it is my opinion that the extension of loblolly pine from a given seed source to points outside its natural range should not affect initial survival. Unquestionably, it may have a great effect on later survival. But for the first five years of this study, the principal differences were found in height growth as related to seed source.

With respect to height growth, trees originating from Atlantic Coastal Plain sources grew more slowly on the average than trees from other sources. Differences among individual seed sources were found to be statistically significant. There is a very real difference between such sources as Maryland and South Carolina, which average 6.9 feet and 6.5 feet respectively, as compared with north Alabama, Georgia, and Tennessee sources, with averages of 9.3, 8.8, and 8.4 feet. This is obvious from an inspection of Figure 1.

Trees planted inside the natural range of loblolly pine tend to grow faster than those planted outside. However, this is only a tendency and is not invariably true. Of the four plantings averaging best in height growth, two are inside the natural range and two outside. Also, of the four plantings showing the poorest height growth, two are inside the natural range and two outside. However, as will be noted in Table 2, the average heights vary only by .8 of a foot in five years and this may not be statistically significant. Also, if results are examined carefully, it is obvious that the poorest growing plots were at the north extension of the tests in Illinois and Kentucky while the best growth was obtained in Alabama, probably due to a climatic or soil factor. Exploration of climatic factors such as maximum temperature, rainfall distribution and amount, soil or other factors, may further becloud or clear up the real facts. These factors will be further analyzed.

A further analysis shows that plots with the highest survivals generally contain the tallest trees. This relationship was found significant by statistical tests. As can be seen from Table 2, for plantings in Jefferson County, Alabama, and in Anderson and Union Counties, Tennessee, survivals of 85 percent have average 5-year

heights of 11.2 and 9.5 feet respectively, while the lowest survivals found in Mississippi and Kentucky, (26 percent and 52 percent survival) had average heights of 5.2 and 5.5 feet respectively. This indicates that seedlings showing good survival the first year or two can, as a general rule, be expected to make good height growth, and that poor survival is indicative of a poorly adapted seed source.

In an effort to check the effect of distance between the point of seed collection and planting locality, an analysis proved that distance was a signficiant factor in survival but not in height growth. Table 4 will bear some study from this standpoint. You will note that the plantations are arranged according to good, satisfactory and poor height growth. This shows that poor survival and poor growth go together; also that seed brought from long distances does not do as well generally as seed collected within a few hundred miles of the planting site. However, there are so many exceptions to this that no definite conclusion can be drawn. No rules can be established. For instance, good plantings were obtained from Georgia seed as far as 820 miles from the seed source and with Tennessee seed as far as 500 miles from the seed source. On the other hand, a poor planting showing poor growth in north Mississippi resulted from seed collected only 40 miles away. Other factors must therefore be studied in order to determine the locality from which loblolly pine seed may be collected for best results in any given area. To say that seed should be collected only within 50, 75, or 100 miles, or any given number of miles from the seed source is not sufficient. Later experience with these plantations and further study will, we hope, give us more significant information on this important rule of thumb.

In summary, certain tentative conclusions subject to further verification can be drawn:

1. It is highly probable that seed from Atlantic Coastal Plain sources will result in poor survival and poor growth if used for reforestation outside the natural range of loblolly pine. Present indications are that this is also true for north Mississippi. Tennessee, Arkansas, Kentucky, and Illinois should avoid seed from Atlantic Coastal Plain sources.

2. High juvenile survival and good height growth of loblolly pine go together and show a significant correlation. Good loblolly plantings can be expected to attain a height in excess of 10 feet in five years.

3. The survival and growth of loblolly pine for all seed sources is progressively better in plantings progressing from north to south. There is probably a definite northern limit beyond which other pine species can be expected to do better with less risk. Further analysis of climatic factors should assist greatly in establishing the zone within which loblolly pine can be expected to be successfully established as an economic venture.

4. There is a definite lowering of early survival with increasing distance from seed source, but the many exceptions make it obvious that we do not have all of the facts and further study is necessary.

Future plans call for the remeasurement of these plots at age 10 years. However, we hope that the agencies responsible for each set of plots will report regularly any unusual circumstances that cause undue mortality or reduction in height growth. It is obvious that at the end of 10 years it would be of little value to know that differences exist unless we know the reasons for those differences.

Table 1. Average Survival and Height of Five-Year Old Loblolly Pine by Sources of Seed

Origin of seed	Survival, percent	Height, feet
Atlantic coast:		
Maryland	51	6.9
South Carolina, lot 2 1/	44	6.5
Virginia	51	7.9
Average	49	7.2
North inland:		
Alabama	74	9.3
Mississippi	60	8.0
Tennessee	75	8.4
Average	70	8.5
South inland:		
Alabama	74	8.0
Georgia	83	8.8
Mississippi	61	7.9
Average	73	8.1
All, average	57	8.0

1/ Third year survival, total height adjusted to five-year basis (actual 3-year height, 3.9 feet). The original planting from North Carolina seed failed and was replaced the following year by South Carolina seed lot 1, which also failed. The South Carolina seed lot 2 planting was established in winter 1951-1952.

Table 2. Average Survival and Height of Five-Year Old Loblolly Pine by Planting Locations

Planting Location	Survival, percent	Height, feet
Inside natural range:		
Alabama, Jefferson Co.	85	11.2
Alabama, Marshall Co.	45	7.0
Mississippi, Lafayette Co.	26	5.2
South Carolina, Union Co.	76	8.8
Average	58	8.4
Outside natural range:		
Arkansas, Newton Co.	68	9.4
Illinois, Hardin Co.	69	5.2
Kentucky, Marshall Co.	52	5.5
Tennessee, Anderson & Union Cos.	85	9.5
Average	70	7.6
All locations, average	64	8.0

Table 3. Average Survival and Height of Five-Year Loblolly Pine by Seed Origin and Planting Locations

Origin of seed	Planted within native range				Planted outside native range			
	Alabama, Jefferson County	Alabama, Marshall County	Mississippi, Lafayette County	S. Carolina, Union County	Arkansas, Newton County	Illinois, Hardin County	Kentucky, Marshall County	Tennessee, Anderson & Union Counties
Survival, percent								
Atlantic coast:								
Maryland	75	21	17	73	52	55	22	79
S. Carolina, Lot 2[1]	79	4	0	62	10	69	38	90
Virginia	71	21	6	69	58	49	60	78
North inland:								
Alabama	94	61	31	94	79	61	88	95
Mississippi	77	48	37	71	75	59	56	68
Tennessee	94	81	42	67	94	85	66	87
South inland:								
Alabama	98	62	29	96	69	79	68	93
Georgia	94	73	46	96	98	89	75	94
Mississippi	83	36	27	75	75	71	31	83
Average height, feet								
Atlantic coast:								
Maryland	10.2	6.2	4.1	8.2	8.4	3.4	4.3	8.0
S. Carolina, Lot 2[2]	7.6	6.6	-	7.9	5.0	4.0	4.6	8.1
Virginia	12.0	4.8	5.1	8.8	9.3	5.0	5.7	8.8
North inland.								
Alabama	12.6	7.4	6.6	10.7	11.1	6.0	6.4	11.7
Mississippi	11.3	7.4	4.7	8.3	10.2	5.2	6.6	9.5
Tennessee	12.2	6.1	6.2	8.3	10.6	7.3	5.4	9.8
South inland:								
Alabama	12.1	7.3	4.1	8.9	9.4	5.1	5.4	10.4
Georgia	10.7	7.7	7.9	9.3	11.5	5.9	6.4	10.2
Mississippi	11.8	7.9	4.1	9.0	9.9	5.4	4.6	9.2

1/ Third year survival. The original planting from North Carolina seed failed and was replaced the following year by South Carolina seed lot 1 which also failed. The South Carolina seed lot 2 planting was established in the winter 1951-1952.

2/ Adjusted to 5-year heights; average 3-year heights were 3/5 of the values shown above.

Table 4. Loblolly Pine Seed Source Plantings Grouped by Survival and Height Class[1/]

Survival	Seed source plantings grouped by height classes and accompanied by distances in miles between each seed collection and planting location		
	Good (over 10 feet)	Satisfactory (5 to 10 feet)	Poor (under 5 feet)
Good (over 70 percent)	N. Ala.--50, 230, 320, 400 S. Ala.--140, 410 Ga. --140, 150, 820 Md. --740 N.Miss.--140, 290 S.Miss.--120, 360 Tenn. --100, 180, 500 Va. --700	N. Ala.--220 S. Ala.--440, 440, 450 Ga. --80, 210, 260, 290 Md. --440, 480 N.Miss.--470 S.Miss.--370, 400, 460 S.C. --340, 500 Tenn. --100, 200, 260 Va. --420	
Satisfactory (40 to 70 percent)		N. Ala.--30, 260 S. Ala.--220, 390 Ga. --290 Md. --990 N.Miss.--180, 240, 290, 360 S.C. --160, 880 Tenn. --240, 280 Va. --370, 660, 670, 970	Md. --690 S.C. --620
Poor (under 40 percent)		N. Ala.--170 Md. --680 S.Miss.--200 S.C. --460 Va. --620, 800	S. Ala.--220 Md. --700, 850 N.Miss.--40 S.Miss.--130, 320 S.C. --610, 640

1/ Five-year height measurements in all cases except the South Carolina seed source which was three-year old; these height values, however, were projected to a five-year basis for purposes of comparison.

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7. PROGRESS REPORT ON LOBLOLLY SEED SOURCE STUDY AT BOGALUSA

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During the period December 27-30, 1926, there was established on the lands of the Great Southern Lumber Company by the Southern Forest Experiment Station a small loblolly plantation consisting of pine seedlings grown from four different geographic sources of seed. The seed for this study was collected in the fall of 1925 from Livingston Parish, Louisiana; Montgomery County, Texas; Clarke County, Georgia; and Howard County, Arkansas. All seedlings were grown in the Little Buffalo nursery of the Great Southern Lumber Company in Bogalusa, thus eliminating many possible nursery variables.

The original plantation consisted of two 1/2-acre blocks with the trees within each block planted in this order: Row 1, Louisiana; Row 2, Texas; Row 3, Georgia; Row 4, Arkansas. Six rows were planted from the seedlings of each seed source. There was no randomization of treatments and some questions may be raised concerning the possible effect of competition as a result of this systematic arrangement of rows. Further historical data concerning this plantation are available on pages 14 and 15 of USDA Agricultural Monograph 18, dated 1954.

At 22 years these plantations were thinned by arbitrarily taking the odd numbered trees from one row and the even numbered trees from the next, etc. This was done to give maximum spacing and to some degree minimize unequal competition which then existed. Trees were removed regardless of size, crown class, rust infection, etc., numbered position within the row being the only criterion for thinning.

This past year each of the trees within this plantation has been systematically remeasured by personnel of our Management Section cooperating with Phil Wakeley of the Southern Station. The following data have been extracted by Phil Wakeley from our IBM card summaries and are presented very briefly for your consideration at this time.

1. Total height. Figure 1 shows the average total height of trees within each one-inch diameter class, plotted by the geographic source of seed. It is at once evident that from 6" to 12" DBH the Louisiana source exceeds in total height the Arkansas source by 6 to 8 feet, Georgia source by 5 feet, Texas source by 1 foot.

The average total height for all trees of each source ran: Louisiana, 59.1'; Texas, 50.5'; Georgia, 49.6'; and Arkansas, 42.1', a spread of 17.0'. In the case of pulpwood height, measurements were to a 4" diameter outside the bark. Note on the same chart that the Louisiana source has an even larger merchantable spread than in the total height figures. Actually, the local trees by diameter class exceed in merchantable height the Arkansas source by 9" - 10", the Georgia source by 5'; and the Texas source by 3' - 4', a net difference of one or two sticks of pulpwood per tree of the same DBH class.

2. Diameter breast high. Assuming that the trees left after thinning were representative of the total population, the total average increase in diameter during the 6 years since thinning has been as follows: Louisiana, 1.4"; Texas, 1.0"; Georgia, 1.5"; and Arkansas, 0.5". Local source trees have made a diameter growth increase of nearly 3 times that of the lowest in this test.

The average diameter breast high for the four seed sources is: Louisiana, 8.1"; Texas, 6.2"; Georgia, 6.7"; and Arkansas, 5.2". This gives the local seed a spread of 2.9" above the lowest.

3. Average pulpwood per tree. The effect of increase in diameter as well as the effect of greater pulpwood length of the individual trees by diameter classes is reflected in the average pulpwood content per tree. The average for the Louisiana stock ran .104 cords; for Texas, .038; for Georgia, .055; and for Arkansas, .019 cords.

This indicates that the average Louisiana seed source trees contain three times as much pulpwood per tree as the Texas source, twice as much as the Georgia, and approximately five times the volume of the average Arkansas trees.

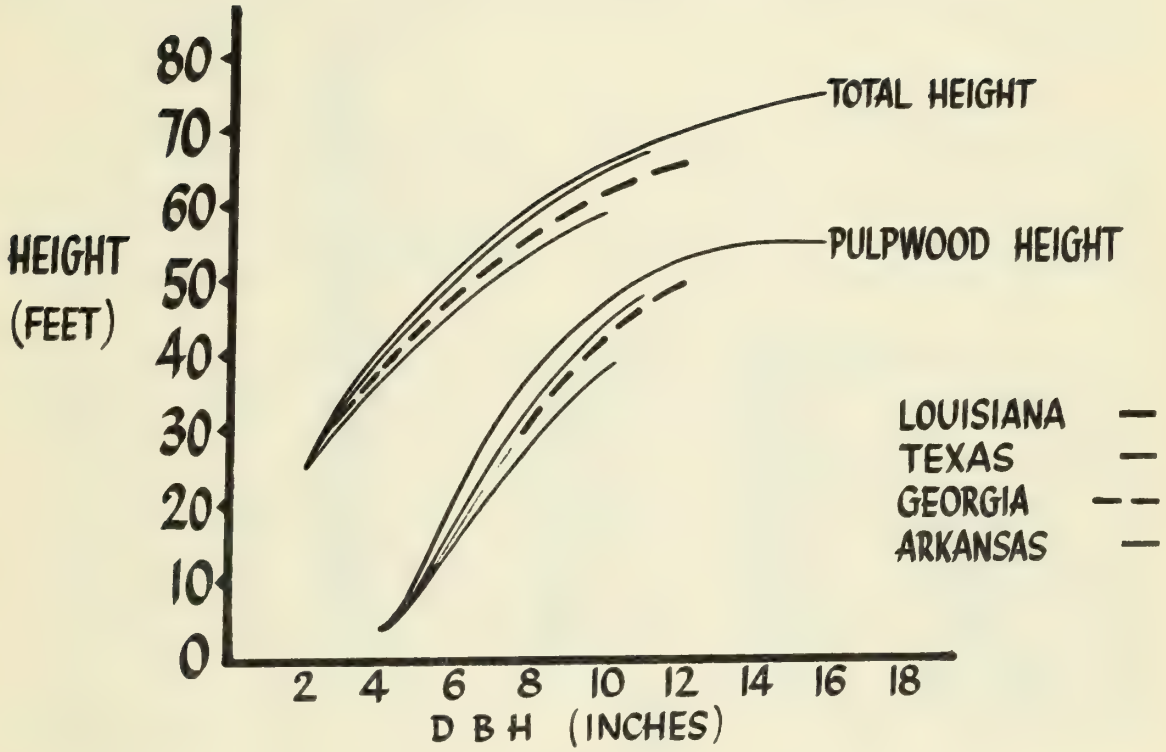

Figure 1.--Total height and pulpwood height, by geographic source of seed. Twenty-eighth year remeasurement. Bogalusa, La.

4. Volume per acre. The volume per acre at the present time is shown in figure 2. Please note the spread in volume per acre from the Louisiana seed source at 32.2 cords to Georgia at 15.3 cords; Texas, 11.3 cords; and Arkansas, 5.7 cords. To this should be added the 1922 thinning per acre which would bring the volume up to 50.7 cords for Louisiana; 23.2 cords for Georgia; 22.6 cords for Texas; and 12.7 cords per acre for the Arkansas seed source. These total production figures in growth per acre to date show that the Louisiana trees have grown 1.81 cords, while the Texas trees have produced 0.81 cords; the Georgia, 0.83 cords; and the Arkansas, 0.45 cords per acre per year for the period since outplanted. From these figures have been deleted the border or outside-row trees, so that this is a conservative presentation of the data. The annual growth spread of 1.36 cords times the average price of pulpwood gives considerable weight to the significance and to the advantages to be gained by seed-source selection.

5. Form class. Figure 3 shows the form class measurements which were taken on this examination. Please note that with two exceptions it has taken trees from other sources longer to reach a given diameter breast high and also that when they have attained this diameter, they are of a lower form class and therefore contain less pulpwood as has been indicated in the averages presented previously.

6. Rust infection. The 28th year remeasurements indicate that on the residual stand, after the 22-year thinning had been made, are present many trees containing fusiform stem cankers. These trees were tabulated to check earlier measurements and are summed up as follows: Louisiana, 2.2%; Texas, 2.1%; Georgia, 25.0%; Arkansas, 22.0% of the trees with stem cankers. In addition to this high susceptability indicated by number of stem cankers it was noted that there was a considerable number of new or relatively new branch cankers on the trees, particularly those from the Georgia and Arkansas source. The contributing effect of these trunk cankers to mortality as well as their susceptability to wind breakage is a further point in favor of proper seed selection.

Summary

This test at Bogalusa laid out by the Southern Forest Experiment Station in cooperation with the Great Southern Lumber Company, although small in size, has made a substantial contribution to our knowledge concerning geographic source of seed. The data presented exclude the outer rows of the sample, thus reducing to a minimum the effect of border trees. In the light of the figures presented and making a generous allowance for the effects of competition by the plantation arrangement, local results emphasize the desirability of the selection of local Louisiana seed for future loblolly plantation stock in our Washington Parish area for maximum production per acre.

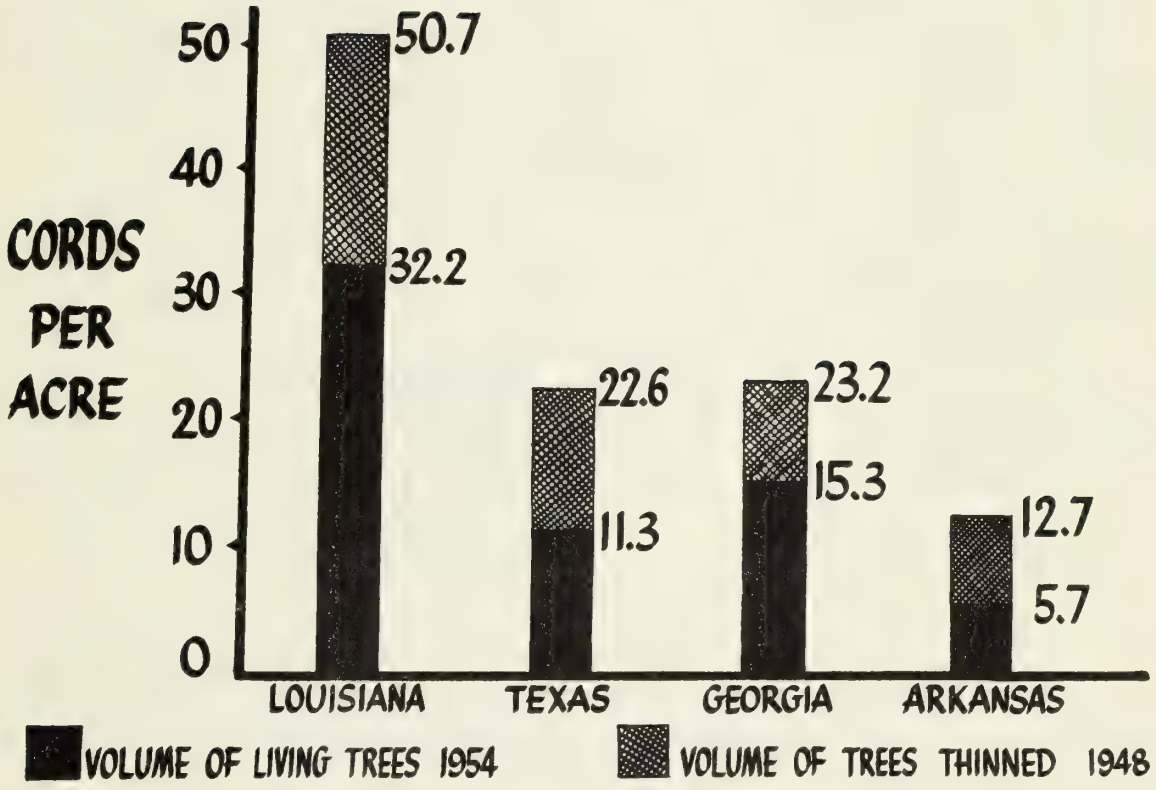

Figure 2.--Total production per acre, by geographic source of seed. Twenty-eighth year remeasurement. Bogalusa, La.

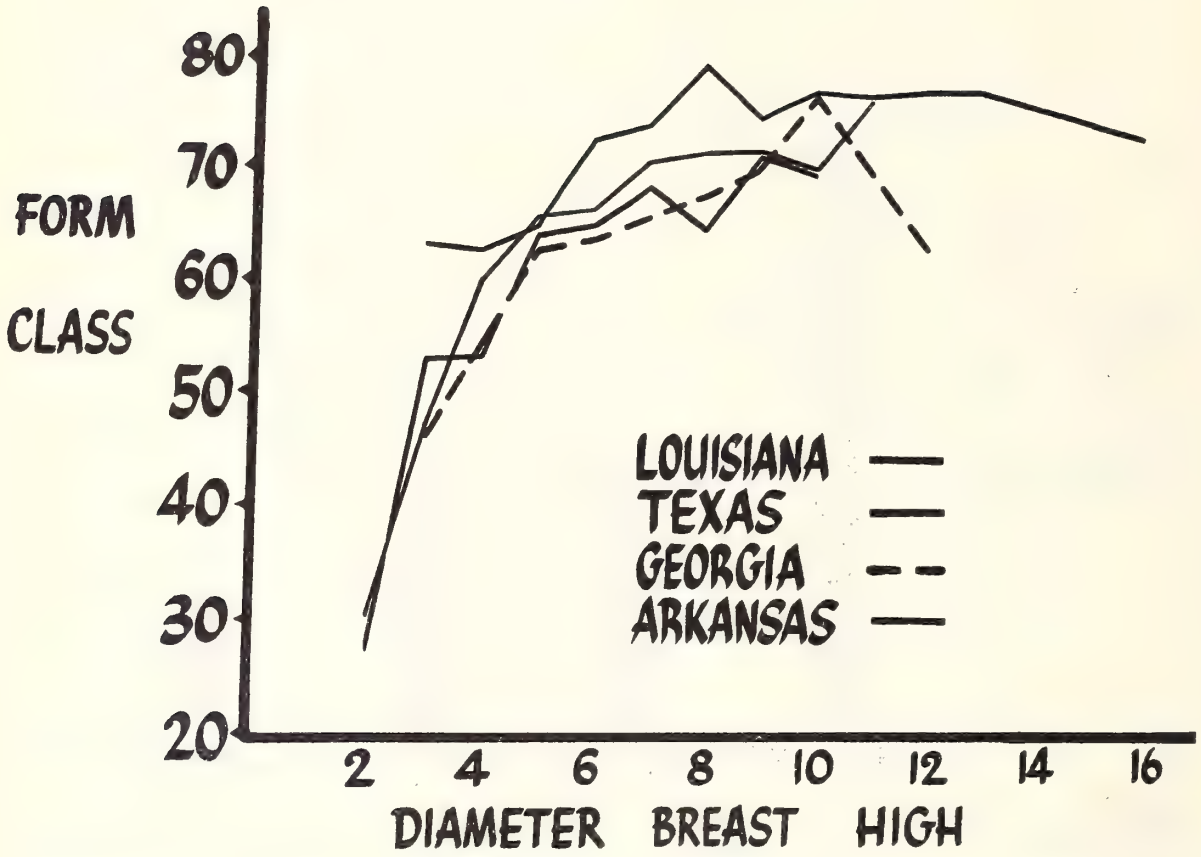

Figure 3.--Form class over d.b.h., by geographic source of seed. Twenty-eighth year remeasurement. Bogalusa, La.

8. SHORT-TIME AND LONG-TIME POSSIBILITIES OF SELECTION IN FOREST TREES

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The subject assigned to me in this conference on accomplishments in forest tree improvement in the South is the "Short-Time and Long-Time Possibilities of Selection in Forest Trees." Before we get involved in what may be a technical discussion of "maybes" and "if" in forest tree improvement, a definition of selection is in order. One that applies very well to forest tree improvement work is given in the 1936 U. S. Department of Agriculture Yearbook. It was included in a glossary prepared by the American Genetic Association.

Selection Defined

By definition selection is: "The choice, from a mixed population, of the individuals possessing in common a certain character or a certain degree of some character. Two kinds of selection may be distinguished: (1) natural selection, in which choice is made automatically by the failure to reproduce--through death or some other cause--of the individuals who are not "fit" to pass the tests of the environment (vitality, disease resistance, speed, success in mating, or what not); and (2) artificial selection, in which the choice is made consciously by man, as a plant or livestock breeder, for characters of value to man."

Natural Selection

Note that a distinction is made between natural selection and artificial. The tree breeder has little control over natural selection, but he can utilize the products of natural selection. We have just heard a discussion of "geographic" races, or "seed source" studies. It has been pointed out that many races are a result of environmental factors that exert selection pressure differing from that in other areas. Natural selection then creates opportunities for selection of races, strains, ecotypes or other groups that occur over geographic space within the natural range of a species. Within races there may occur other types of variation attributable to various genetic effects which provide opportunities for single tree selection.

Artificial Selection

The second type of selection, artificial selection, is of great value to the tree breeder. Through selections in mixed populations have come many kinds of better plants and animals. Selection of the better individuals of common crop plants and animals was applied for centuries before the discovery of sex in plants in the Eighteenth

Century--fairly recent times in the history of agriculture. The selected individuals then crossed naturally or were inbred and created additional populations to which selection was applied. If vigor declined it was restored by outcrossing. Each step, over the centuries, in improving the strain might have been small, but the accumulative effect has been large, so large, in fact, that it is impossible to accurately tell the wild ancestors of some crop plants such as corn.

Basis for Selection

Notice that our definition states selection is the "choice from a mixed population". There must be a mixture of genotypes within a species in order for selection to be effective. This is logical because obviously if no genetic variants existed all individuals would be similar genetically and produce uniform offspring. Genetically, where no variation exists in the genotype, the individuals are a pure line--they are homozygous. This is important because it points up one of the limitations of selection. It is not effective in pure lines. Selection can only isolate variants, it cannot create them.

What basic evidence have we that forest tree species are mixed populations genetically? First, consider the plight of the dendrologist. Beset with difficulties in describing species, he has created varieties, races, and forms to describe differences between groups within species. The many taxonomic categories in species such as Douglas-fir and Scots-pine are strong evidence that these species are not genetically uniform. A variety of slash pine was formally named recently. Several publications have discussed racial variation in loblolly pine. Only recently has the Forest Service, U. S. Department of Agriculture, recognized pond pine as a species rather than as a variety of pitch pine.

Trees probably contain a number of genes for each trait that is important economically. The genes occur in different combination so that no two trees are exactly alike. The lack of uniformity is apparent in every planted stand and is in sharp contrast to the amazing uniformity of trees from rooted cuttings of a single tree or the inbred progeny of a single tree.

Mutations cause still another type of variation. Mutations are sudden changes in a gene or genes that are passed on through inheritance. Many ornamental plants of unusual type are mutants and numerous commercial varieties of citrus and other fruits are of this origin. The varieties and forms have been isolated by selection and preserved over the years by vegetative propagation.

Certain plants may have more than the usual number of sets of chromosomes. These are polyploids. Some authorities consider this a type of mutation while others do not. Polyploidy occurs frequently in hardwoods and species form polyploid series within certain genera. One species will have two sets, which is normal, while other will have three, four, five, or more.

From this discussion we learn that, within a given tree species, there may be differences between trees or groups of trees that are a result of natural selection--different combinations of genes, mutations, and polyploidy. Each may cause certain desirable or undesirable traits, and they will be inherited in some degree by their offspring. They are the causes for variation in trees and provide the basis for selection.

Certain tree species may be extremely uniform genetically. If so, there will be very little opportunity for improvement through selection. Selection must be very rigorous if it is to be effective. Any undesirable genes the species may have will have to be replaced by those of another species through controlled breeding. If the species is very uniform, there will be little need for careful selection of breeding stock to represent the species in hybridization with other species.

If tree species are variable there is opportunity for selection and isolation of the outstanding individuals or races. Also, there is opportunity for transfer of genes by breeding within the species. In crossing with other species it will be necessary to use several parent trees in order to sample the species. Otherwise, the hybrid offspring may be the offspring of two variants rather than a typical species hybrid.

The practice of leaving well-formed seed trees and collecting seed from trees of good form should result in more uniform stands, and they should be uniformly good. The degree of uniformity in the natural stand or plantation will depend upon the qualities of the parent trees, and, if only a few are involved, the offspring probably would be fairly similar; but if a large number of parent trees are involved, such as in a shelterwood or seed tree stand, more variation between individual offspring is to be expected. It should be pointed out here that not all differences between trees are important economically, and this should be taken into consideration when criteria for selection of crop trees or mother trees are chosen; also, when studies of phenotypic variation are made.

Studies of Variation Needed

If the value of selection is dependent upon inherent variation, then studies of variation are fundamental to a program of forest tree improvement. There has, however, been a curious lack of willingness on the part of the tree breeders to study variation. In our current programs we find much-to-do about selection of superior trees; but one does not select superior trees, period! He first studies variation. It may be informal--a casting of eyes over two or more trees growing together and a quick comparison of their good and bad points--but study variation he certainly does. He also tries to separate environmental and genetic effects on tree form and growth. No one wants superior trees as such--they want superior trees that produce superior offspring.

The full potential of selection as a crop improvement technique will never be obtained without full knowledge of the variation within plants. Let us not neglect this work any longer. Also, let us report our studies in variation for the benefit of others.

We should learn the range of inherent variation for each important trait in all species of southern pine. We know right now many differences between the major species, but we know less about the minor species, and much less about differences within species. There is a tremendous volume of potential breeding stock among the species and varieties of southern pine. There will be a need for breeding with foreign species in some instances, but perhaps we can get by without using them and thus avoid the problems concerned with the long-time testing of introduced tree species.

Studies of variation may be made by transplant studies of various races such as you have just heard discussed in connection with the seed source studies. Form, wood quality, and other traits can be studied in natural stands and plantations, where a number of environmental factors are constant. Studies of natural stands should provide the basis for additional studies where precise methods are used. Performance of the progeny is the important criterion of inheritance of a trait and progeny may be obtained from seed after wind pollination, controlled pollination between trees, or inbreeding. If vegetatively propagated material (because in this material genetic effect between plants is constant) can be included in progeny tests, an extremely wide range of inheritance data will be obtained. Thus, inheritance data should come from tests that include vegetatively propagated material, in addition to seedlings after inbreeding, controlled breeding with another tree, and wind pollination. By adding a site variable, the interaction of genetic factors and some of the environmental factors can be determined.

The inheritance of commercially important traits must be known if selection is to be highly efficient, because we should know how much weight to give each trait when selected trees are evaluated. The superiority of a plus tree is the sum of the products of the economic value of an important trait and its strength of inheritance. It is fruitless to give great weight to a trait that is not strongly inherited. Thus, our current recommendations for selection of plus trees must be based on estimated values for inheritance. Obviously, the recommendations will become more precise as our knowledge of variation and inheritance increases.

Benefits of Selection

In the immediate future, selection will isolate existing genotypes of local species. Based on what we know now of variation and inheritance, these trees will be straighter and branches will be smaller; the stems will have less taper and there will be very little

forking. They may grow faster and be less susceptible to attacks by pests. Studies of variation followed by selection of valuable types will bring to use valuable natural mutations, if they occur.

Over the years, selection and controlled breeding will create tree types much superior to any in existence today. Not only will they grow faster than the average trees today, but they will be uniform. Most of the undesirable genes will be bred out of them, and all trees in a stand will have high utility.

Current results in selection of individual trees and studies of variation will be given in papers which are to follow.

Summary

In summary, selection practices based on studies of variation will disclose valuable genes or valuable gene complexes if they exist within tree species. Selection will not create new types, it merely isolates single trees or races of trees. Many of these variants will be commercially valuable and form the basis for so called "improved strains". Other variants will, over the years ahead, have value as parent stock in selective breeding programs to create gene complexes superior to those found in nature.

Afternoon Session, January 5
Moderator, A. D. Folweiler

9. STATUS OF THE SUPER-SEEDLING STUDY AT TVA'S CLINTON FOREST NURSERY--FALL 1954

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In 1951 Tennessee Valley Authority began selecting unusually tall seedlings from seedbeds in its forest nursery at Clinton, Tennessee. Our intent is to follow the development of these super-seedlings to see whether some turn out to be exceptionally fast growing strains which can be used in breeding work and as a source of seed for improved forest nursery planting stock. So far, 174 loblolly, shortleaf and white pines have been selected. But the study is not old enough yet to provide significant or conclusive results.

The purpose of this report is to outline briefly the background of the study, describe how we make the selections, and relate what our experience has been to date.

Basis of Super-Seedling Study

Selection of exceptionally tall individuals from nursery seedbeds is an empirical approach, and it is one of several lines of attack used in an effort to improve the quality of forest planting stock. Seed source tests, now being conducted on a wide scale, will provide information on seed collection areas as related to planting sites. The location and special handling of good quality stands for select seed production should yield almost immediate benefits. Selection of outstanding individual trees for vegetative propagation and cross-pollination with other superior selections will build up a core of select plant material for ultimate large scale production of high quality seed. These selections are ordinarily sought in the woods where one has the advantage of observing fully developed trees. The principal advantage of nursery selection is its convenience and low cost. While we expect that a number of the apparently superior seedlings later will prove to be run-of-the-mill stock, the method is still worthwhile if only a few of the selections actually prove to be superior in growth or quality.

Although modern nursery practice has developed to a point where huge quantities of relatively uniform planting stock are produced each year, exceptionally tall individuals occasionally appear in the seedbeds. These oversize seedlings may result from any of several causes so they must be watched for several years before the inherently vigorous can be distinguished from the rest.

The possibility of exerting a positive influence on the production of future forests by nursery selection has been pointed out by Lindquist (5). Sherry (9), working with the longleaf pine in South Africa, selected the largest seedlings on planting trays and established two test plots, one containing vigorous and the other average or normal seedlings. After five years over 70 percent of the trees on the vigorous plot exceeded 20 feet while none in the normal plot had yet attained this height.

Hybrid vigor, seed size, and local variations in seedbed fertility are sometimes responsible for unusual seedling size. In Sherry's case some of the vigorous trees proved to be hybrids, although after five years seven true longleaf pines were as vigorous as the best of the hybrids. Aldrich-Blake (1, 2), working with Corsican pine, and Gast (4) and Mitchell (6, 7), working with Scots and white pine, observed a direct relationship between seed weight and the weight of seedlings at the end of the first growing season. However, the difference in seedling size associated with original size of seed gradually wears off. Both Spurr (10) and Righter (8) observed that the effect of seed size on seedling size was at first pronounced but that it later diminished in contrast with the sustained effect of other factors associated with seed origin. Older studies reviewed by Baldwin (3) and the Forest Service, U. S. Department of Agriculture (12) indicate that seed size may affect the growth of pine up to the ninth year after planting. Tall seedlings resulting

from local differences in seedbed fertility are distinguished from other super-seedlings in that they occur in clumps or bands rather than as exceptionally tall individuals that stand out above their immediate neighbors in the seedbed.

In spite of the fact that inherent vigor cannot be distinguished until after several years, it appears worthwhile to try nursery selection on a systematic basis. The purpose of the super-seedling study is to determine whether or not nursery selection is a practical method of segregating exceptionally vigorous strains of forest trees. Present plans call for continuing the selection of loblolly, shortleaf and white pine over a five year period, and following the development of these trees in arboretums during the succeeding five years, after which genetic differences ought to become discernable.

Selection of Super-Seedlings

Selection is made on the basis of height and is done in the fall immediately before lifting (13). Seedlings showing the greatest superiority over the average of adjacent seedlings are designated as super-seedlings. First, a general reconnaissance locates exceptionally tall seedlings. These are marked and measured, along with the heights of 25 adjacent seedlings. The average of each 25-seedling sample is then computed and subtracted from the height of its corresponding tall seedling. Those with the greatest difference, chosen at a rate of roughly one for every 200,000 seedlings[1/] in the seedbed, are considered super-seedlings and are transplanted to the arboretum. Each super-seedling is paired with a control or check seedling taken from the same spot in the seedbed and having approximately the computed average height of the 25-seedling sample.

During the past four seasons approximately 40 million loblolly, shortleaf, and white pine seedlings have been examined. From this number, we have selected 174 super-seedlings (Table 1). Since different seed lots handled in the nursery are kept separate throughout the various operations, the geographic origin of each super-seedling and control is known.

Preliminary Results

The most striking thing about the super-seedling plantation so far is the height variation that already exists in the older trees. Some of the super-seedlings have consistently outgrown their controls (Table 2). In one instance the ratio is almost two to one (Table 3). In other cases, super-seedlings have grown about the same or even slower than their controls.

1/ In the case of the 2-0 white pine planting stock, tall seedlings occurred less often than in the other species and the final selections ran at a rate of about one for every 425,000 seedlings.

Table 1. Super-Seedling Selections of Loblolly, Shortleaf and White Pine from Seedbeds in Clinton Forest Nursery, 1951 - 1954

Species	Year	Number of Seed Sources	Number of Seedlings	
			Examined	Selected
Loblolly pine	1951	2	6,412,000	33
	1952	3	3,595,000	18
	1953	5	6,289,000	30
	1954	9	16,265,000	78
	Total	19	32,561,000	159
Shortleaf pine	1953	3	2,300,000	10
	1954	1	1,735,000	6
	Total	4	4,035,000	16
White pine	1954	3	3,758,000	9
All species	All	-	40,354,000	174

Table 2. Survival and Relative Growth Performance of Super-Seedling Selections

Year selected	Number of super-seedlings--1954			Number of seedlings originally selected
	Dead	Growing		
		Slower than controls	Faster than controls	
		Loblolly pine		
1951	6	15	12	33
1952	9	3	6	18
1953	1	8	21	30
1954	-	-	-	78
		Shortleaf pine		
1953	0	2	8	10
1954	-	-	-	6
		White pine		
1954	-	-	-	9

Table 3. Total Height of Super-Seedlings and Corresponding Paired Controls Measured at One-year Intervals

Year measured	Average total height of seedling, feet				Total height of best seedling, feet	
	All--1:200,000		Best fifth--1:million			
	Super	Control	Super	Control	Super	Control
			Loblolly Pine--1951 Selections			
1951	1.3	0.6	1.1	0.5	0.9	0.4
1952	1.7	1.2	2.0	.9	2.5	.9
1953	3.5	2.8	4.1	2.5	4.7	2.5
1954	6.2	5.4	7.3	4.7	8.8	4.7
			Loblolly Pine--1952 Selections			
1952	1.3	0.6	1.2	0.8	1.4	0.8
1953	2.1	1.2	2.1	1.2	2.0	1.3
1954	3.7	2.7	4.1	2.6	4.5	2.6
			Loblolly Pine--1953 Selections			
1953	1.3	0.5	1.2	0.5	1.1	0.4
1954	2.6	1.5	2.7	1.2	3.0	1.3
			Loblolly Pine--1954 Selections			
1954	1.3	0.5	-	-	-	-
			Shortleaf Pine--1953 Selections			
1953	1.0	0.4	1.1	0.5	1.0	0.4
1954	2.2	1.2	2.6	1.2	2.1	.8
			Shortleaf Pine--1954 Selections			
1954	1.2	0.5	-	-	-	-
			White Pine--1954 Selections			
1954	1.4	0.6	-	-	-	-

For example, 12 of the 27 surviving 1951 selections have continued to grow faster than the controls. The most vigorous trees of this group, representing roughly one of every million seedlings examined, average 7.3 feet in height in contrast to 4.7 feet for their paired controls. When all fast and slow growing selections are combined, super-seedlings average 6.2 feet and controls 5.4 feet. Similar groupings and height differences are also evident in the newer selections, though less

pronounced. Comparisons among the different super-seedlings are made on the basis of differences in height that existed between each seedling and the corresponding control at the end of the 1954 growing season. While the average difference was 0.8 foot for all 1951 selections, it was 2.6 feet for the best fifth and 4.1 feet for the best single selection. It is interesting to note that this tree did not stand out from the rest the first year, being only 0.9 foot in contrast with the average height of 1.3 feet for all super-seedlings. The same thing was observed in a number of other instances, as is evident in the data presented in Table 3.

The relatively high proportion of super-seedlings outgrown by their controls may be explained in part by the fact that the seed was not screened and kept distinct by size grades. In all probability a number of the paired selections were merely plants which happened to originate from an unusually large and an average size seed. This variation could be reduced in the future by screening all of the seed into two or three size groups. As a matter of fact, Zobel (11), in a similar study in Texas, is using seed graded to size in an effort to eliminate as many variables as possible.

Indications based on a casual inspection of the super-seedling arboretums are that we have not picked up any hybrids so far which might account for some of the vigorous growth. However, this aspect will be investigated more thoroughly when the super-seedlings get their first critical evaluation.

Future Plans

At the end of five years, the fifth-year height increment will be used to evaluate the super-seedlings. The difference between each super-seedling and its paired control, measured in terms of the standard deviation of all controls, will be assigned a rating on the basis of probability: 0 for greater than 0.1, 1 for less than 0.1, 2 for less than 0.01, 3 for less than 0.001, etc. At the same time we will obtain information on the chromosome number of each promising super-seedling.

Plans for continuing the study call for re-evaluations and thinnings at intervals of five years. Beginning the tenth year, super-seedlings with a rating of less than 2 and controls that are poorer than average by a probability of less than 0.01 will be removed. Checks threatening to interfere with the growth of super-seedlings rated 3 or better will also be removed.

As time goes on we may be able to improve our selection techniques. Certainly, in time we should have the evidence to show whether nursery selection is a feasible approach to the discovery of genetically fast-growing strains of forest trees.

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10. DROUGHT HARDY TESTS OF LOBLOLLY PINES *Pinus taeda L.*

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During 1951, a study was initiated to determine if drought hardy strains of pine could be found that would improve survival and growth on droughty planting sites. Need for this work is critical, especially in the Western Gulf Coast Region where there have been widespread plantation failures as well as losses in older plantings in dry years such as 1951 and 1954. Some landowners have about given up planting as a hopeless task. Although it is hard to get a stand of pine trees started on these critical areas, once the trees are well established their growth rates and the per acre yields are very satisfactory.

The approach to the drought problem was three pronged: i.e., by selection of what appeared to be drought hardy strains; by hybridization, combining drought hardiness with other desirable characters such as fast growth; and by testing introductions from regions of low rainfall and high temperatures, especially from Mexico and the Mediterranean countries. The tests were started at an ideal time since 1953 was quite dry and in our area the drought of 1954 was severe. These two years gave ideal conditions for making tests of drought hardiness.

The results reported here are for the selection phase of the work, which was concentrated on loblolly pine. Although the research is not yet complete, very interesting results have been obtained. The presence of drought hardy pine strains can hardly be doubted after the past three years' research, but it still remains to be seen how the growth of the apparently drought hardy strains compares with that of loblolly pine from other sources.

We in Texas have "made-to-order" conditions for selections of drought hardy strains of loblolly pine. Beyond the western edge of the Southern Pine Region there are found isolated islands of pine growing under conditions of low rainfall and high temperature. These "Lost Pines", as they are called, are found up to 120 miles west of the Southern Pine Region, growing under rainfall of 25 to 45 inches,

depending on the year. Temperatures are high. Rainfall often comes as heavy showers of short duration, and soils are for the most part rocky and poor. Altogether conditions are very severe.

From this area eight open pollinated selections were made from different sites in three separate Lost Pine stands. The following discussion with slides will show the survival differences between the progeny from the Lost Pines and from the more Eastern check material. Tests were replicated on six different areas for three years, two replications being made each year when stock was available. Four of the test areas were located in the Post Oak Region, in deep sands, on droughty sites, in low rainfall areas. The other test areas were in the East Texas Pine Region at our main research area at Fastrill and at Many, Louisiana. A subsidiary test at Millard, Mississippi, showed the same pattern of survival.

Conditions on all test areas were very severe in 1954 and in some during 1953. To illustrate the severity in 1954, there was no measurable rainfall from May 26 to early in October. During this time temperatures were high, often over 100°F and several times were over 110°F. The survival pattern for this area is shown by the following table of survival:

Florida source	8%	
North Carolina source	22%	
Two Louisiana sources	62%	
Texas sources		
Bastrop County	88%	Lost Pine sources
Fayette County	80%	
Another Bastrop source	100%	
Angelina County	75%	(Western edge of Southern Pine Region)

(The slides presented showed what happened in other test areas. Too severe conditions finally killed everything, but the drought hardy strains remained alive several weeks longer than the checks, which ordinarily would be long enough to catch a rain.)

The results just presented to you by graphs certainly look encouraging. They are not the whole answer, however, and only additional tests and more time will give a final answer. Two questions need to be solved: i.e., do we have drought resistant strains and if we do, what kind of trees will they produce? The first is partially answered, as the graphs show. The second is being answered. To date the drought hardy stock has grown as well as any stock tested. In fact, in many cases it is better. As Ray Goddard expressed it, "It appears that the drought hardy stock not only can survive, but also can continue to grow under severe conditions!" Questions as to limb form and other characteristics of drought hardy trees can only be answered in the future as the plantations come closer to maturity.

Some one might object that we are testing only geographic races. To see what might happen within an area, seeds were collected from a moist, a dry, and an intermediate site in the Lost Pines. Lack of seed crops has prevented a follow-up, but in the 1953 tests the seed collected from the dry sites in both Bastrop and Fayette Counties produced seedlings that survived better than those collected from the moist sites. This pattern was repeated in five of the six test areas--in the sixth, survival was equal. Such local race tests are incomplete, but have yielded interesting results in their early stages.

It certainly appears that loblolly pine has certain "strains" that can tolerate more drought than others.

11. POSSIBILITIES OF GENETICS RESEARCH IN SOUTHERN HARDWOODS

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The principal purpose of these notes is primarily to try to assure that Southern Hardwoods will not be entirely overlooked in considering the possibilities and logical course of genetics research as they have too often been in the past in other connections. They supply 8 to 10 percent of the total saw timber requirements of the United States, serving many especially exacting and essential purposes for some of which we are already having to import suitable timber. Therefore, if there is any probability of substantial results, Southern Hardwoods should certainly command a commensurate proportion of the genetics effort.

None of us who are working on the problems of this sub-region is particularly qualified as a geneticist nor has anyone, so qualified, particularly considered any of our species but cottonwood. Therefore, we can only speculate and surmise. Nevertheless, we have become convinced that the possibilities may be even greater than in pine and perhaps easier of realization and that some definite immediate necessities are already in view. Accordingly, I presume to present here a sketchy outline of our observations and thoughts on the subject.

First; a few remarks upon the apparent possibilities and opportunities:

The simple fact that we have so very many species and natural hybrids, not only all together but within several genera, may in

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1/ Maintained in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Research Group.

itself indicate great genetic possibilities. This especially since there are great and obvious inherent differences between species in site adaptation or ecological requirements, growth rates, form and branching habits, susceptibility to insect attack and other degrading and degenerating influences, technical properties of the wood, reproductive and competitive capacity, etc.

However, the greatest and most practical opportunities are no doubt to be found in the very great range in numerous apparently inherent characteristics within species. Such characteristics as general form and branching habit (incl. tendency to epicormic branching), susceptibility to attack by wood boring and bark scarring insects and to mineral stain, diameter and height growth rates, wood properties, tolerance of drought, tolerance of soil saturation and flooding, adaptation to plastic soils, etc., appear more or less inherent in individual trees. It is not at all uncommon to find trees, conspicuously superior or inferior in one or more of these characteristics, growing in groups or groves of quite ordinary trees of the same species and approximate age class, under apparently identical circumstances.

For instance, perhaps Nuttall oak is the least drought tolerant bottomland species of great economic importance, especially on low waxy clay flats. Nevertheless, even on such sites an occasional lush, green tree; usually of superior stem quality, too; may be found within a grove of trees that are largely dead or dying under apparently the same ecological circumstances. Likewise, cherry bark oak is especially notable for rapid diameter growth and good quality, as to both prospective lumber grade and technical properties of the wood. Still, within a group or a grove, growing under apparently homogeneous conditions at a general diameter rate of 3 to 4 inches in 10 years, a conspicuous individual may often be found to be growing at the rate of 6 or 7 inches, and even more, in 10 years. Rather generally, such trees have notably superior stems in form and quality as well.

Next; as to silvicultural and economic needs and the advantages that may accrue in serving them: Although hardwoods on appropriate hardwood sites will grow even faster than pine, the urgency to attain rapid growth is relatively even greater because hardwoods must attain substantially greater size to have the same economic consequence. Likewise, although there are great economic advantages in good form and high quality in all species, not only are these advantages multiplied several times in hardwood but failure to attain them in some degree carries the insufferable penalty of economic extinction. Thus, there not only may be exceptional reward for genetic accomplishment but, considering the deplorable degeneration of our stands through over 40 years of high grading, such accomplishment is a definite necessity. Actually our most generally essential silvicultural measure, after protection, is improvement cutting and it is fundamentally a crude genetic measure.

Also, there are relative advantages in the carrying on of genetics work in hardwoods such that results in some lines may be more readily attained. The most obvious and perhaps greatest of these is the ability of perhaps all of the species to reproduce vegetatively. Some do so with complete freedom while others require special stimulus and coaxing, but so long as it can be accomplished with any dependable facility at all, the advantage must be very substantial. There is, too, the ability of the poplars and willows, at least, to fruit on cut twigs kept for a few weeks in protected receptacles in the greenhouse. Obviously, this vastly simplifies the breeding procedure. I frankly do not know whether we have other technical advantages or not but, considering the long list of diverse species which we must at least consider, it would be strange if we cannot discover other advantages to offset the complexity.

Finally, regarding what little we are doing and may do in the near future:

Through a long course of experimentation, we have discovered and established the pre-requisites and techniques for successful direct field planting of cottonwood cuttings. This has comprised our principal effort, thus far, in planting and we chose this species for concentration because of its phenomenal growth rate and its very superior ability to reproduce vegetatively. The principal technical obstacle remaining to be surmounted is the extreme variability in vigor and quality and the high proportion of weaklings and runts in the woods-run lots of seedlings and recent sprouts from which planting stock has had to be cut. Dependably uniform stock of the highest vigor and quality is needed to warrant the necessary outlay in site preparation and cultivation. Given it, however, we feel that we will be well on the way to realization of the species' potential production of about 4 cords per acre per year or about 1,000 feet of logs, plus 2 cords of wood.

Accordingly, we have made a small exploratory beginning at trying to identify and multiply clones of uniform, superior cutting stock from cuttings taken from selected trees of pole and small saw timber size. There are, as yet, only four such trees on trial and only a few cuttings from each rooted so that no definite report or even prediction can be made although indications are encouraging. This work will be greatly expanded this spring. We have, also, tried culling, by 30 to 40 percent, run-of-the-bar seedlings used for cutting stock in establishing two cutting nurseries. The produce will be culled still further before field planting. Although we are just now up to the first field planting, there is an apparent great improvement in the stock.

Finally, we are looking forward to work with a variety of species through experimenting with practical means of inducing cuttings to root more readily. Substantial possibilities are indicated with sycamore and green ash and meagre possibilities with Nuttall oak while

sweet gum shows none. We hope to enable direct field planting of unrooted cuttings as with cottonwood but any success at all should facilitate future genetics work. The only breeding which we visualize undertaking, as yet, may be crossing of certain poplars in the hope of developing a good tree adapted to swamp planting.

So much for the hardwood situation as we now see it dimly and the little that we are already doing about it. However, the main points of my message are, simply, that there is certainly a large place for hardwoods in any long range genetics program for the South. Also, that we are most anxious for advice and guidance as to how best to cooperate in filling that place.

12. SELECTING SLASH PINE FOR GREATER YIELDS OF TURPENTINE

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Turpentine, rosin, tar, and pitch, often referred to as naval stores, have been important forest commodities since the earliest days of our Colonial history. Production of turpentine and rosin from the oleoresin (gum) of living longleaf and slash pines reached its peak about 1908. Since then competition from other sources, unstable market conditions, and other economic problems have caused a gradual decline in the gum naval stores industry. At present about 94 percent of the production is concentrated in southeast Georgia and north Florida with only small amounts being produced in Alabama, Louisiana, Mississippi, and South Carolina. Probably the gum naval stores industry has reached the bottom of its long decline as its principal competitor, the wood naval stores industry, cannot expand further because of dwindling stump supply. The other major source of naval stores, the sulphate pulp industry, while able to supply great quantities of turpentine, cannot provide sufficient rosin to meet estimated future requirements. One of the main uses of rosin is for paper size and since the production of pulp is expected to double in the next 20 years and the supply of wood rosin will certainly begin to decline within another decade, there appears to be ample need for a gum naval stores industry in the future.

There is however, one large problem. Turpentining as practiced at present in natural forests involves a large amount of hand labor and while some improvement has been made through the new bark chipping and acid technique, the industry lags far behind other agricultural pursuits in the efficient use of manpower through mechanization, hybridization, and improved cultural techniques. If the industry

is to survive and prosper in the future it must develop strains of pine trees that yield large quantities of oleoresin. Such trees should be grown in plantations where they can be cultivated intensively and worked efficiently. A good start has been made in this direction at the Lake City (Florida) Research Center of the Southeastern Forest Experiment Station.

On August 19, 1941, a tree improvement program for gum naval stores production was initiated by H. L. Mitchell and his associates. Systematic measurements of the gum production of thousands of mature trees identified 12 superior specimens that yielded at least twice as much gum as ordinary pines. These trees then were control-pollinated to obtain seedlings of known parentage. At the same time cuttings were propagated vegetatively for the establishment of a progeny plantation in which the relative merits of the different parents could be determined.

Now let's digress a minute while we consider the factors that enable some trees to produce more gum than others.

In 1951 Dr. C. S. Schopmeyer discovered that the flow of oleoresin from mature slash pines was influenced by the viscosity of the gum, the average size of horizontal resin ducts, and the number of such resin ducts per square centimeter.

In 1954 Dr. François Mergen made similar tests on the offspring of the high-yielding turpentine trees. One-inch square wounds were made near the base of the seedlings and the resulting flow of gum collected for a period of four weeks. The viscosity of the gum was compared with that of the mother trees and found to be a closely controlled hereditary characteristic. There was also a close correlation between the viscosity of the oleoresin and the rate of flow or yield. These tests revealed beyond question that saplings from high-yielding parents also produced above-average quantities of gum.

At the same time additional checks were made for evidence of other inherited traits. For example, three-quarters of the offspring of one crooked parent also are crooked. Saplings from another set of parents appear to be susceptible to pitch canker. Still other seedlings have not developed properly. Strains with these and other undesirable traits are being eliminated in the final selection of breeding stock.

Breeding a second generation must be deferred until young trees are old enough to produce pollen and conelets, usually at 8 to 10 years of age for the most prolific and 10 to 15 years or longer for many slash pines. So the geneticist seeks to hasten or stimulate flowering by changing normal sapling development through strangulation or partial girdling of the main trunk, by heavy applications of fertilizer, and other treatments.

Some flowers have appeared on a few of the best saplings and these trees have been control-pollinated again to see if strains of even greater gum yields can be developed.

In 1954 scions from the most desirable of the tested high yielders were grafted to ordinary planted 2-or 3-year-old seedlings for the establishment of seed orchards. Although some seed of high-yielding strains have been obtained from a few exceptionally fruitful trees, mass production in quantity will not be possible for several more years. Then the seedlings so obtained must reach a minimum diameter of 9 inches at breast height before commercial turpentining is feasible. This will take another 15 to 20 years, depending upon the productivity of the site and any intensive cultural treatments that may be devised.

This effort to breed a superior strain of oleoresin-producing slash pine has already consumed 13 years, and a minimum of 20 more years will elapse before commercial turpentining becomes possible. We know now that the job can be done. How intensively it is to be undertaken is something for the gum naval stores industry and the general public to decide.

13. OCCURRENCE OF PESTS IN SOUTHWIDE PINE SEED SOURCE STUDY

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and
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The installation of this gigantic cooperative seed source study is one of the landmarks in the research on artificial regeneration of the southern pines. The study will indicate whether geographic races of the southern pines exist, what their geographic boundaries are, and to what extent it is safe to move seed within the boundaries of the species. Much additional information, which you might call "fringe benefits", can also come from this study.

When this project came into being, it was realized by the then Division of Forest Pathology, Bureau of Plant Industry, Soils and Agricultural Engineering, that here was a "gift from the gods" laid right in our laps. For several years we had been cognizant of the need for a study of plantation diseases. A few relatively small-scale

studies had been started, but of course none approached the scope of this cooperative enterprise. Therefore we felt we'd be remiss in our duties if we failed to offer our whole-hearted participation to the Subcommittee on Geographic Source of Seed. This offer of participation was accepted by the Subcommittee. It was arranged that pathologists of the Southern and Southeastern Forest Experiment Stations would examine the bulk of the plantations in their respective territories. Based upon our meager past knowledge of plantation troubles we felt that destructive insects as well as diseases should be included. Accordingly the Forest Insect Laboratory at Gulfport was asked to and agreed to cooperate in following those plantations in the Southern Forest Experiment Station's territory. I believe that now the entomologists of the Southeastern Forest Experiment Station are likewise cooperating in this venture.

Plans call for dormant-season examinations annually for the first five years, then at the end of the seventh and tenth years, and at each fifth year thereafter; examinations to be in conjunction with the respective cooperator wherever feasible. We are now in the midst of the second annual examination.

Results

The primary result of the first examination (i.e., one year ago, at the end of the first year in the field) was that no plantation was seriously damaged by pests. Some were virtually free of the depradations of diseases and harmful insects while others were damaged to varying degrees, but the usefulness of none was seriously impaired by disease and insect pests. I am afraid, however, that such will not continue to be the case through subsequent years.

To illustrate the type of results we are obtaining and the possible implications, I would like to present some slides illustrating the more common pests and some data obtained at the end of the second year from two Gaylord Container Corporation plantations.

The two most prevalent insect pests encountered are Tetralopha robustella Zell. (the pine web worm), and Rhyacionia frustrana C (the Nantucket pine tip moth).

(Slides of Tetralopha)

The insect feeds on seedlings of all four of our major pine species. Growth is most certainly retarded as a result of defoliation and in some cases this insect is apparently the direct cause of death of the seedling.

(Slides of tip moth)

This insect is particularly damaging to loblolly and shortleaf seedlings. By killing back the terminal and lateral shoots it causes

the seedling to assume a much-branched, ragged form, precluding the prediction of future form class from juvenile stock.

(Slides of fusiform rust)

Among the diseases, the fusiform rust (Cronartium fusiforme (Pk.) Hedgc. and Hunt) of slash and loblolly seedlings is the most important, especially as the brown spot needle blight disease of longleaf is controlled in these plantations by spraying. The rust varies greatly in intensity between plantations but can cause serious losses through the malformation and death of affected young plants.

(Slides of Pales weevil (Hylobius pales Hbst.))

This weevil commonly attacks pine seedlings planted in an area from which older pine trees have just been removed. It has been a minor pest in the seed source study but is one that must be contended with in the establishment of progeny testing areas on recently cut-over land.

We are sorely in need of control measures for the Nantucket tip moth and the pales weevil.

(Slide of data)

1. Loblolly Series 2. These data are not meant to be representative of the entire Southwide Study but merely present the picture as it occurs with a selected series in two Gulf-area plantations, with mention of some possible implications. The two plantings are at about the same latitude and possibly forty miles apart.

Let us note first (Table 1) the data in column 3, i.e., the percent of living seedlings infected with fusiform rust by the end of the second season in the plantations. It is evident that on the average there is less fusiform rust in the Mississippi planting than in the Louisiana one. Note however that the upper-listed five seed lots in both plantings and the upper six in the Louisiana one show the most rust infection. These six lots are from east of the Mississippi River, while the other three are from near or west of the River. At present, this is just an indication, but with the same general tendency toward rust susceptibility exhibited in Wakeley's 1926 test.

Tip moth infection, shown in column 4, is fairly high throughout; averaging fifty-five percent of the individuals in the Mississippi plantation and forty-three percent in the Louisiana one. There are no evident differences in susceptibility to this insect between the various seed sources. However, there is a possibility that some seed lots will recover with less permanent growth defects than others.

Again with Tetralopha, there are no large differences between plantations or between seed sources.

Table 1. Loblolly Series 2, end of second year in plantation

Seed Source		Pearl River County, Miss.					Washington Parish, La.				
				Affected by:					Affected by:		
No.	County and State of Origin	Survival	Height	Fusiform rust	Tip moth	Tetralopha	Survival	Height	Fusiform rust	Tip moth	Tetralopha
		Percent	Feet	-.-.-.-Percent-.-.-.-			Percent	Feet	-.-.-.-Percent-.-.-.-		
303	Onslow, N. C.	91	2.1	7	67	10	94	3.9	21	46	10
307	Newberry, S. C.	97	2.2	8	59	16	89	3.3	15	50	17
311	Clarke, Ga.	95	2.3	14	65	6	95	3.2	16	41	13
331	Spalding, Ga.	88	1.6	9	32	14	94	3.4	20	46	11
317	Clay, Ala.	90	1.8	10	54	14	90	3.0	19	42	11
321	Prentiss, Miss.	95	1.8	3	52	16	88	3.0	12	41	13
323	Livingston, La.	90	2.1	6	68	8	89	2.9	2	36	13
327	Clark, Ark.	89	1.4	0	49	24	87	3.1	5	45	13
329	Hardemann, Tenn.	89	1.5	3	44	23	88	2.6	6	36	17
Average		92	1.9	7	55	15	90	3.2	13	43	13

Table 2. Slash Series 1, end of second year in plantation

Seed Source		Pearl River County, Miss.					Washington Parish, La.				
				Affected by:					Affected by:		
No.	County and State of Origin	Survival	Height	Fusiform rust	Tip moth	Tetralopha	Survival	Height	Fusiform rust	Tip moth	Tetralopha
		Percent	Feet	-.-.-Percent-.-.-			Percent	Feet	-.-.-Percent-.-.-		
201	Colletin, S. C.	86	1.8	5	4	14	81	2.9	25	2	12
203	Baker, Fla.	82	1.5	5	2	24	83	3.2	39	2	21
205	Polk, Fla.	86	1.4	1	1	21	-	-	-	-	-
207	Monroe, Ala.	84	1.6	5	1	23	84	3.1	28	-	-
209	Harrison, Miss.	93	2.1	4	3	14	-	-	-	-	-
211	St. Tammany, La.	81	2.0	3	1	14	73	2.6	28	2	23
Average		85	1.7	4	2	18	80	3.0	30	2	19

(Slide of Data)

2. Slash Series 1. These data (Table 2) are from the slash pine series at the same two plantations as above.

Fusiform rust is quite low at the Mississippi site with no differences between seed sources with the possible exception of the very low reading (one percent) for the Polk County, Florida source; however, seedlings from this source resemble the "South Florida" slash more than the true slash pine. Infection is quite high at the Louisiana plantation; considerably higher than on loblolly. The only difference between seed sources is possibly the quite high (thirty-nine percent) infection of the Baker County, Florida source compared with the others (twenty-five to twenty-eight percent). Previous studies with slash pine have failed to show differences in rust susceptibility attributable to the geographic source of the seed.

In conclusion, I believe that by following the occurrence of disease and insect pests in this Southwide Pine Seed Source Study we will not only learn which pests are the most serious but will gain much needed knowledge about their habits, life histories, and host range, and always stand the chance of finding a resistant or tolerant race or strain of the host.

14. POSSIBILITIES AND LIMITATIONS OF HYBRIDIZATION IN PINUS

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When I mentioned the title of my paper to Dr. N. T. Mirov, plant physiologist and biochemist at the Institute of Forest Genetics, he said: "Tell them that the possibilities are unlimited." It is easy and, perhaps, natural to take such a view. The pines exist in such diversified abundance that--given crossability among many of the species, fertility in the hybrids, the infinite future, and the consummate technical ingenuity of mankind--almost any reasonable objective can be attained through synthetic breeding in Pinus. In this, I am reminded of the first four verses of a sonnet to Vittoria Colonna by Michelangelo, a translation of which, as I recall, runs as follows:

> "The master craftsman hath no thought in mind
> That one sole marble block may not contain
> Within itself; but this we only find
> When the hand serves the impulse of the brain."

1/ Maintained in cooperation with the University of California.

The genus Pinus, consisting according to Buchholz (1) of about 90 species, may well be likened to Michelangelo's all-encompassing marble block. Distributed circumpolarly in the Northern Hemisphere, it ranges from the equator to the Arctic Circle; and within that span, from sea-level to sub-alpine elevations and from swamplands to desert-edges. These facts imply, and the literature attests, that an enormous amount of genetic diversity--the raw material of breeding--is impounded in the genus. In the aggregate, the genus embodies, as no single species does, all the elements essential for synthesizing many different kinds of superior new products, adapted to numerous places and purposes.

Synthesis in Breeding Analogous to Synthesis in Chemistry

The problem, however, is not one of artistic carving such as confronts sculptors, but rather one of synthesis such as confronts chemists, entailing the application of principles through appropriate techniques and procedures. I have long felt that interspecific hybridization, with selection standing at its stirrup, has much in common with chemical research, particularly, as I shall attempt to show, in its potential dynamism; and I daresay that, with pines at least, progress through such breeding will parallel progress in chemical research to a very considerable extent. It will be interesting and perhaps helpful, therefore, to enlarge on this aspect of the subject somewhat.

One of the first concerns of chemists was to discover and describe the elements. Regarding each species of a genus as an element, we may say that the jobs of discovery and morphological description have been well advanced by botanists.

The next step in dealing with the elements was to determine their affinities for other elements and describe the properties of the compounds they form with them. That, of course, is also a major objective of hybridization programs. Some elements, such as chlorine and oxygen, combine with many elements whereas others are inert. Similarly, various pines (P. attenuata, P. echinata, P. ponderosa, P. taeda for example) combine readily with various other species while others (P. sabiniana and P. resinosa, for example) appear to be relatively inert.

The number of substances that can be compounded from the 90-odd elements defies calculation. According to Conant (2), there are about 70 trillion isomers of $C_{40}H_{82}$ alone. Similarly, assuming that each individual that can be obtained from crossing P. echinata and P. taeda and their hybrids, for example, represents an individual isomer, the number of isomers or biotypes, as they are called, that are obtainable from crossing those species would, doubtless, be astronomical in magnitude.

Carrying the analogy further, it is possible to obtain hybrids in which genes of three or more species are represented. A half-dozen

such crosses have already been obtained at Placerville; and doubtless many more will be obtained. Populations of such hybrids are likely to be highly variable. Nevertheless, in two instances at Placerville, they have surpassed two of their parental species in average growth-rate. Such populations abound with exceptional individualities that stand out in conspicuous contrast in nursery tests, and thus provide an abundance of materials in convenient array for selection.

As in chemistry, relatively few of the possible combinations will be of any great practical importance. Actually, relatively few of the possible combinations are likely to be investigated in the next 1,000 years; hence, we are presently concerned only with relatively few of the possible combinations. Nevertheless, even in that sense, "relatively few" may mean very many, indeed. And those that do prove to be important, are likely to be very important, indeed, at least over short periods of time.

It is apparent, then, that synthetic breeding on the species level is roughly analogous to the work of chemists in producing new compounds. It differs chiefly, it seems to me, in that its conceptual basis lacks the high refinement that characterizes the conceptual bases underlying analogous work in chemistry. In short, to borrow an idea from Conant (2), the degree of empiricism in forest tree breeding is relatively high and will remain so for a long time despite the fact that genetic theory is highly developed. For that among other reasons, we must reconcile ourselves for the present to much less precision and consequently to much slower progress than is possible in chemistry. As we learn more about the hidden heredity of the various species, their affinities, the inheritance of their characters, and other pertinent facts, we shall be able to reduce the degree of empiricism in our work and breed for particular objectives with increasing precision and speed. The possibilities, however, are fairly similar, I believe, to the possibilities in chemistry.

Crossability of Pines

Those theoretical possibilities are, of course, contingent upon crossability among many species of a genus and fertility in the hybrids. With respect to the conifers, the possibilities were suggested incidentally by Muntzing (3) in 1933 and definitely emphasized somewhat later by Sax and Sax (5). Muntzing based his assumption of interspecific crossing and hybrid fertility among gymnosperms on the fact that a possible barrier to crossability and hybrid fertility, namely double fertilization, is lacking in the gymnosperms. The Saxes based their conclusion on the results of a study of certain cytological phenomena in conifers. Briefly, they observed relatively high uniformity within genera in chromosome number and morphology. As lack of uniformity in those phenomena is frequently a barrier to crossability and fertility among angiosperms, they concluded that species differences within coniferous genera are mostly genic; and hence, that differences between many species of a genus may be too small to prevent species crossing

and fertility in the hybrids. Those contributions by great scientists, together with various other considerations, were responsible for the sudden shift of emphasis from selection to hybridization at Placerville in 1940.

The possibility envisioned by Dr. and Mrs. Sax is now a well-established fact so far as the pines are concerned. About 40 F_1 hybrids, many of which have already exhibited high fertility, have been produced at Placerville, some of them in considerable abundance. I have no doubt that similar results will be obtained in most other coniferous genera.

Number of Hybrids Obtainable in Pinus

The practical possibilities obtainable from hybridization in Pinus, as in any other genus, are, in part, a function of the number of different hybrids that can be made. The more the crosses, the greater the possibilities! If all the 66 species recognized by Shaw (6) in his excellent classification of the pines could be crossed with each other, 2,145 F_1 hybrids, and a much larger number of hybrid progenies (F_2's, backcrosses, tri-species hybrids, etc.), could eventually be obtained. Such a prospect could generate a lot of fanaticism in pine-breeders, among some of whom there may already be too much. Unfortunately, only a small fraction of that number of F_1's is likely to be obtained; for crossability is largely a function of closeness of relationship and the relationships between most of the pines are not close. Hence, it will be salutory to get back to earth and make an estimate of the number of crosses that we may reasonably expect to obtain.

Shaw's classification provides a good basis for such an estimate. It recognizes two sections, each divided into two subsections, each of which contains three or more groups of species. It is convenient to regard these groups as relationship groups because, on the basis of similarity in morphological characters, the species within a group are, by and large, more closely related to each other than they are to species in other groups. Assuming that this classification is accurate and that crossings can be obtained between all the species within groups but not between species in different groups, the possibilities would be as shown in Table 1.

The numerical possibilities shown in Table 1 are too high in my estimation. None of the southeastern members of Australes has been crossed to any of the western contingent of that group. Hence, the total for that group is much too high. All attempts to cross the Macrocarpae have failed; a number of crossings in both Lariciones and Insignes have likewise failed, and there is good reason to suppose that the two species in Leiophyllae will not cross. The total for Cembra probably is fairly accurate; for inter-group crossings in that subsection tend to compensate for intra-group failures in it. On the basis of Shaw's classification and our results to date, I should be satisfied with less than 200 crosses.

Table 1. Crossing possibilities in Pinus by Shaw's relationship groups

Section	Subsection	Group	Number of Species			Number of F_1 Hybrids Possible		
			Group	Subsection	Section	Group	Subsection	Section
Haploxylon (soft pines)	Cembra	Cembrae	3	-	-	3	-	-
		Flexiles	2	-	-	1	-	-
		Strobi	7	-	-	12	-	-
			-	12	-	-	25	-
	Paracembra	Cembroides	3	-	-	3	-	-
		Gerardianae	2	-	-	1	-	-
		Balfourianae	2	-	-	1	-	-
			-	7	-	-	5	-
			-	-	19	-	-	30
Diploxylon (hard pines)	Parapinaster	Leiophyllae	2	-	-	1	-	-
		Longifoliae	2	-	-	1	-	-
		Pinea	1	-	-	0	-	-
			-	5	-	-	2	-
	Pinaster	Lariciones	12	-	-	66	-	-
		Australes	11	-	-	55	-	-
		Insignes	16	-	-	120	-	-
		Macrocarpae	3	-	-	3	-	-
			-	42	-	-	244	-
			-	-	47	-	-	246
Total for the genus								276

Mass Production of Products of Breeding

Practical possibilities are also contingent upon the ease and speed with which products can be produced in abundance. Mass production of F_1 hybrids, whether from seed or through vegetative propagation, presents a problem of no little apparent difficulty. The magnitude of the difficulty will vary from case to case, regardless of method. As the rootability of hybrid-pine cuttings remains to be studied, there is no point in dwelling on the possibilities in that field just now. Results obtained at Placerville on the number of sound seed obtainable per pollination bag are of immediate concern. It varies greatly from cross to cross. The maxima obtained for a number of crosses are shown in Table 2.

Table 2. Maximum sound seed produced per pollination bag, Institute of Forest Genetics

Hybrid	Sound seed per bag
P. ayacahuita x *P. griffithii*	75
P. echinata x *P. caribaea*	229
P. echinata x *P. taeda*	432
P. jeffreyi x *P. coulteri*	109
P. jeffreyi x *P. ponderosa*	101
P. monticola x *P. strobus*	184
P. contorta x *P. banksiana*	54
P. ponderosa x *P. engelmannii*	175
P. ponderosa x *P. montezumae*	152
P. rigida x *P. taeda*	130
P. strobus x *P. griffithii*	81

Whether or not such yields would be worthwhile, even if they co could be obtained on the average, depends on numerous relationships which time does not permit me to discuss. Average yields of such magnitudes, however, probably would be highly profitable in some cases.

Nevertheless, production of hybrids from hand pollination could supply only a very small part of the seed needed for planting in the South in the immediate future. Perhaps the main benefit to be expected from planting relatively small numbers of F_1 hybrids will be in the large amounts of seed that can be obtained from them. Last fall, we obtained 11,500 sound seed from a single, 16-year old hybrid between shortleaf and loblolly pines.

The Potential Dynamism of Systematic Hybridization

In the foregoing discussion, I have suggested that hybridization is an exploratory process, having highly dynamic potentialities, capable of effecting continuous improvement in products; and I venture to say that, in consequence, some very substantial improvements may be rendered obsolete before they can be utilized on a large scale, just as the dynamism of industry often renders its newest products obsolete almost as soon as they can be marketed. An example of such dynamism may be illustrated by a comparison of several hybrids of ponderosa pine.

The hybrid between ponderosa and Apache pines outgrows ponderosa pine in the habitat of the latter (4). Its superiority is manifested in height- and diameter-growth, foliage production, and probably in root-development as well. The hybrid between ponderosa and Montezuma pines, which was produced later, outgrows the ponderosa-Apache hybrid by a considerable margin in height, but it lacks the early diameter-growth and root-development of the latter. Figure 1 shows a comparison of the hybrids at 2 years.

The tri-species hybrid, which was produced still later by crossing the ponderosa-Apache hybrid with Montezuma pine, equals the ponderosa-Montezuma hybrid in height and, as Figure 2 shows, has greater diameter, to boot.

In Figure 3 are shown a plot of the tri-species hybrid paired with a plot of ponderosa pine.

In Figure 4 are shown the largest ponderosa pine in the entire nursery growing beside the largest of the tri-species hybrids, also at 2 years.

Thus, through a series of crossing, two suggesting a third, we have apparently succeeded in combining the exceptional height-growth of Montezuma pine with exceptional early diameter-growth of Apache pine in seedlings which, presumably, possess some of the local adaptability of ponderosa pine. This tri-species hybrid seems to be highly superior in important respects to two previously-obtained hybrids of ponderosa pine, each of which was sufficiently superior to the ponderosa pine to justify its use in place of that species in at least part of its range. We may well expect many additional instances of such dynamism in hybridization work.

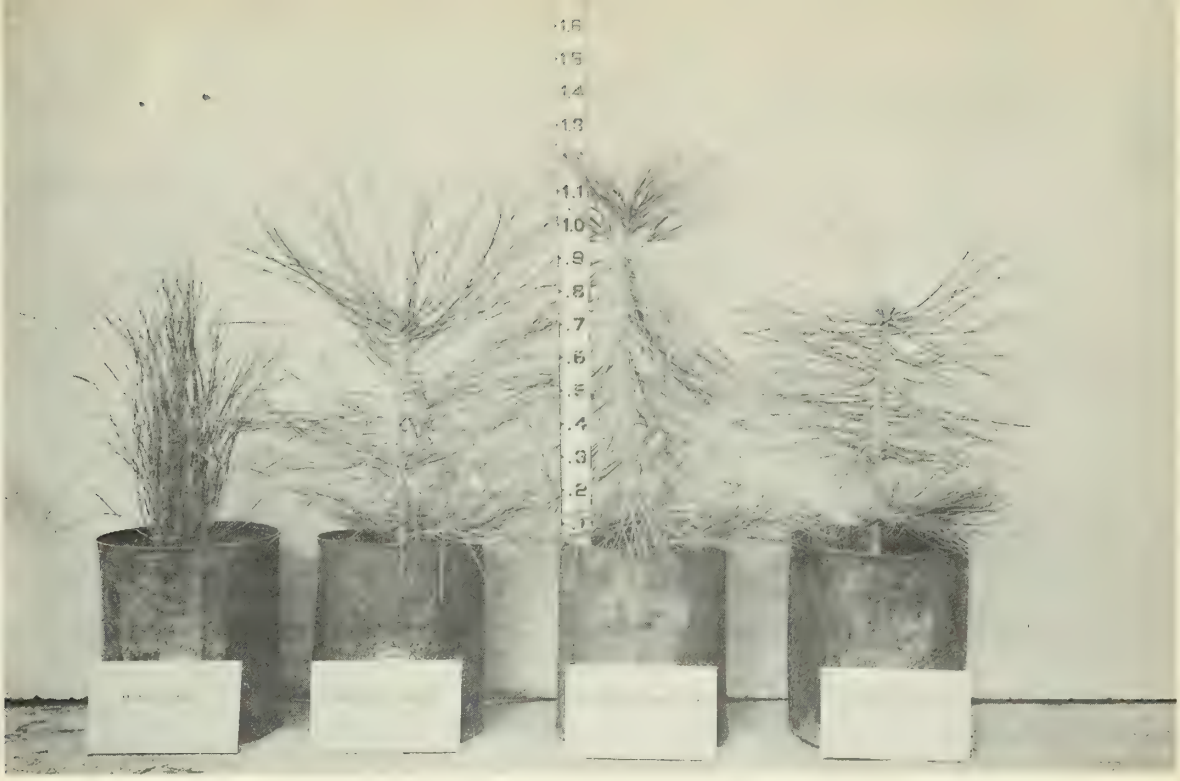

Figure 1.--From left to right: Pinus montezumae, P. ponderosa x P. apacheca, P. ponderosa x P. montezumae, P. ponderosa.

Figure 2.--From left to right: Pinus ponderosa, (P. ponderosa x P. apacheca) x P. montezumae, P. ponderosa x P. montezumae, P. montezumae.

Figure 3.--Front row: P. ponderosa; Rear: (P. ponderosa x P. engelmannii) x P. montezumae; Age: two years. At one year, there was no difference between the two progenies in height, but the hybrid had a highly significant advantage in diameter.

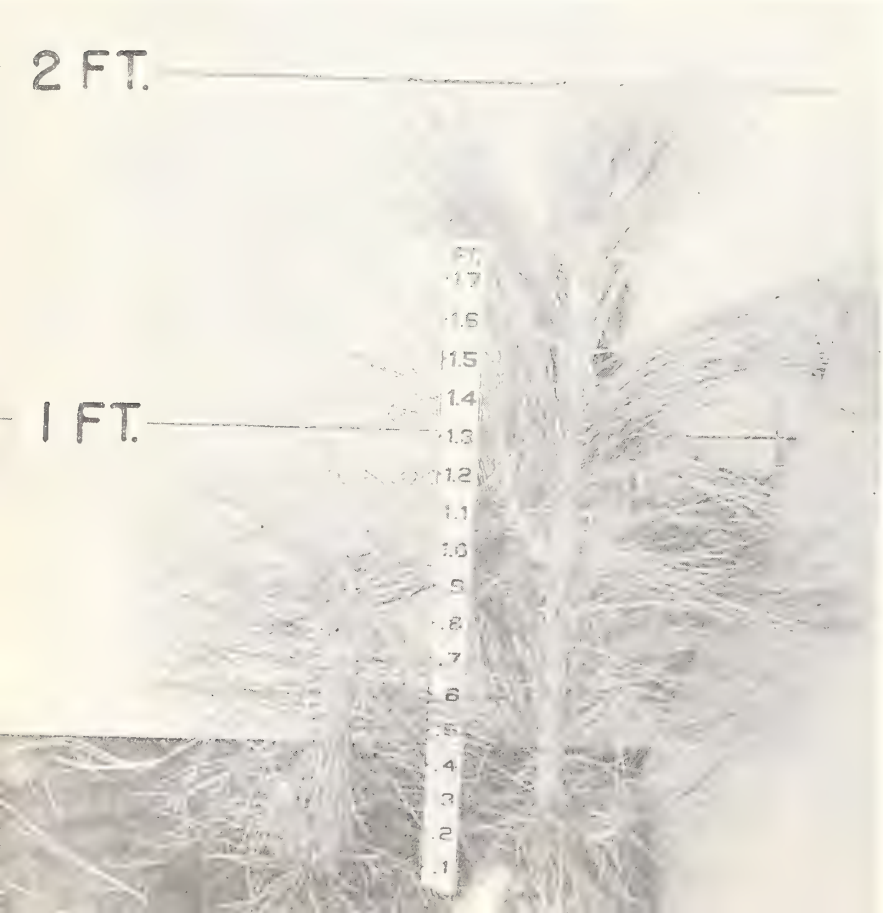

Figure 4.--
Left: Pinus ponderosa;
Right: (Pinus ponderosa x P. engelmannii) x P. montezumae.

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15. SOUTHERN PINE HYBRIDS, NATURAL AND ARTIFICIAL

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When the Chairman of this meeting asked me to talk to this group of Southern Pine men about Southern Pine Hybrids, my first reaction was distinctly negative. Why, I asked myself (and you will probably join me in this question), should anyone not working with Southern Pines be so presumptuous as to try to talk to you about them? However, after some soul-searching bearing largely upon Boston's weather at this time of the year compared to that of New Orleans, I decided to accept.

According to Webster's New International dictionary, unabridged, a hybrid is:

"1. The offspring of the union of a male of one race, variety, species, genus, etc., with the female of another; a crossbred animal or plant. By many plant and animal breeders the term hybrid is limited to a cross between different species, crossbred being used for a cross between races or varieties of the same species.

"2. In genetics, however, the term hybrid is commonly applied to any offspring of parents of different genetic makeup."

According to Knight's Dictionary of Genetics, "A hybrid is the product of a cross between individuals of unlike genetic construction."

Since with the exception of a few special cases progeny in nature result from matings, whether animal or plant, between individuals of more or less different genetic makeup, it follows that virtually all sexually reproduced progeny, even if differing in but one gene, are by definition hybrids.

Nonetheless, while accepting this more general usage for practical purposes, we should keep in mind that in the fullest sense of the word nearly all trees met with in our day to day work are literally hybrids in a greater or lesser degree. No population of trees is so static genetically that it lacks some variability. This variability is, moreover, both blessing and curse to the forester and breeder. On one hand he has found through bitter and too often repeated errors that he cannot promiscuously use a seed stock of a given origin in a new and unselected site far removed from the source with any assurance of the success of the planting. It may or may not succeed, or its success may be of a limited degree according to the degree of adaptability inherent in the seed lot and the sum total effect of the new environment on the planting. In the final analysis, each seed source represents a continuum in time of a more or less narrowly plastic composite of the genotypes of the area resulting from all the selective forces acting at the source of the seed. These forces, in the course of evolutionary history, may well have screened out certain adaptive features originally present in the species when it first moved into its present location. In this way the adaptability range of a species or variety may be progressively narrowed down until we reach a point of local, sometimes edaphic, races of limited adaptive capacity. On the other hand, inherent variability gives the breeder a chance to select individual progeny of potential merit or value to him. For example, by this means we have been able to grow many pine species in the Boston area which are generally not hardy there. The technique is the simplest. Plant a lot of seed from various sources and let winter do the selecting. By this method we have some slash pine of unknown origin, spruce pine from Alabama, Pinus pseudostrobus and some other Mexican hard pines, P. ayacahuite (a white pine also from Mexico), P. massoniana from Southern China, and a number of others. A good hard winter might finish most of them, but for the present they are prospering.

What can be expected from hybrid pines? On what bases do we expect them to be useful? From experience it is natural to draw comparisons with other plants in which hybrids have proved of value. It is easy, by analogy, to expect of hybrid pines what we realize from hybrid corn, for instance, but in the case of corn the breeder has had to be content with increases in yield of 15, 20, or sometimes

30 percent on an overall average. These relatively modest increases have resulted from an intensive and painstaking selection for vigor, disease and insect resistance, adaptability to soils, growing seasons, and numbers of other factors. These carefully inbred selected qualities have been brought together usually in a two generation double cross to endow the hybrid with values transcending those of its parental lines and creating a truly plastic and widely adaptable organism. One acceptable definition of hybrid vigor can be simply stated to be better adaptability to given environmental conditions than that shown by the parental lines. However, an organism displaying hybrid vigor under certain conditions may not do so under others. Every organism is capable of existing within a given range of conditions. Within this total range a narrower band of more nearly optimum conditions prevail, where the organism truly flourishes. On either side of these optimal limits lie belts where existence is possible, but life grows less tolerable as the limits are approached. Hybridization may expand this band or belt of available optimum conditions but will not necessarily have a similar effect on the limits of conditions tolerated by the hybrid organism. On the contrary, a narrowing of the extremes of this marginal survival range on both ends of the optimum range might more likely be expected, thus actually further limiting rather than increasing the overall tolerance of the hybrid organism. If we expose our best corn hybrids to untenable conditions, we cannot expect other than disappointing results. Without the necessary environment the best of heredity is meaningless. One cannot exist without the other, and arguments as to which force is the more important are largely pedantic.

It follows that with hybrid pines we cannot expect exceptional results unless we are willing to provide exceptional conditions. True, we may be able to, in all probability will, increase the growth capacity and broaden the adaptability and tolerance of our pines through proper breeding techniques, but we cannot expect miracles where no basis for such exists. Most of our species have inherent growth capacity exceeding that realized under existing management practices, so in a sense we are in the position of trying to improve on something which we haven't yet fully exploited.

From the available literature and from personal communication kindly sent by several of you, I totaled up eight hybrid southern pines, not including reciprocal and backcrosses. This certainly just scratches the surface of the possibilities of hybridization within the several species existing in the southern part of the country. Certainly some of the five or six so-called minor species have characters of potential value which sound exciting to an outsider. What about the competitive capacity of spruce pine teamed with the qualities of the more virtuous species? Such a combination might help solve to some degree the hardwood weeding problem.

Some, perhaps many, of the possible hybrids may prove worthless. Certainly Sonderegger pine does not lack for detractors, in spite of the fact that it eliminates the grass stage of longleaf. In a region

largely lacking sharp geographic and climatic barriers and containing many interfertile species it is quite probable that many of the theoretically possible combinations have occurred from time to time but have proved to have low survival value and have been lost in the evolutionary mill. The hybrid between Pinus nigra of Europe and P. densiflora of Japan, for example, first produced in this country by Blakeslee, is dying off now at an age of about forty years. Whether or not this early death is due to hybrid unbalance we have too few trees to determine. Progeny from the hybrids show a remarkable variation in stature, ranging from extreme dwarfs, suggestive of transgressive segregation, to plants of normal stature and growth rate. Incidentally, this hybrid simulates to a remarkable degree the common and most polymorphic of the Eurasian pines, P. sylvestris, and suggests possible ancestral lines of that important timber species.

Another important outgrowth of the study of pine hybrids will be the possibility of discovering something of the phylogeny of our species. To be sure, obvious relationships are recognizable in certain pines, but precisely how these relationships came about we do not yet understand in any profound sense. We clearly see characters in common such as sproutability in pitch and shortleaf pine, and pruinose branchlets and other minor characters are common to shortleaf and scrub pine. How many of our present day species represent in a sense a stabilized hybrid swarm resulting from the fusion of species upon their coming together geographically in the great plant migrations following the retreat of the pleistocene ice? The Apache Pine, P. engelmanni, of Mexico, Arizona, and New Mexico shows in its long leaves and grass-like juvenile stage a certain phylogenetic affinity to longleaf. How far back does this relationship go? Are the two pines survivors of a single ancient stock separated now by desiccation of the Mexican plateau and further modified by the introgressive effects of sympatric species?

Up to the present time our approach to hybridization has been largely empirical. We know the capabilities of our existing pines only in a general way and can see possibilities for certain improvements, but we lack almost entirely any soundly developed theoretical understanding of these existing species as biological systems. To reduce the role of empiricism should be one of our major initial tasks in any tree improvement program, and to achieve this goal we need fuller knowledge of the basic biology and relationships of our pines. As such knowledge accumulates through the efforts of groups such as this, empiricism will drop into the background and with the confidence born of sure understanding breeders will be able to deliver trees tailored to specifications.

To comment further upon the role of natural hybridization, it is curious indeed that so few natural hybrids have been reported in this group of highly interfertile species. Sonderegger is, of course, well known, and a few others are reported or suspected. Current evolutionary throught emphasizes the role of hybridization and tends to

minimize, without dismissing, mutation as the principle source of variation. The tremendous impact of man upon the plant communities of this region has certainly, in the sense of Anderson, hybridized the habitat and created situations where hybrids can be expected. I suspect we are only now beginning to know where and when to look for them. The pines with their diversity of requirements and ready crossability seem likely to be peculiarly adept at this sort of evolution. Shaw in 1914 in The Genus Pinus comments: "As the botanical horizon enlarges the varietal limits of the species broaden and many restrictions imposed by earlier systems are gradually disappearing. The cause of the bewildering host of varietal forms connecting widely contrasted extremes seems to be the facile adaptability of these pines." Loock in 1950, commenting on the bewildering complex of Mexican pines says: "It must, however, be added that many intermediate forms, which are ascribable either to evolution or hybridization, still exist and are extremely difficult to classify, when closely related species are concerned."

To very briefly sum up, it seems likely that hybrids, both interspecific and intraspecific, will have a definite place in the planted forest of the future. They can be expected to show wider adaptive tolerance within reasonable limits than their parental types. They can be made to incorporate resistance to various adverse conditions and under proper conditions may outyield their parents in certain cases. They cannot be expected to compensate for poor conditions of site or water supply nor can they replace sound intelligent management.

16. CONTROLLED POLLINATION TECHNIQUES

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and
R. M. Allen, Forester
Southern Institute of Forest Genetics
Southern Forest Experiment Station, Gulfport, Miss.
Forest Service, U. S. Department of Agriculture

As earlier speakers have dealt with some of the objectives to be achieved by controlled pollination and hybridization, we will now briefly discuss the means for attaining those ends.

In controlled pollination, loose, wind borne pollen must be prevented from reaching the female strobili or flowers at the time they are receptive and the desired pollen must be placed in contact with the flowers. As the essential ingredients in any tree breeding project are flowers, we might well begin with a hasty glance at the sexual

structures of pines, the genus to which this discussion will be restricted.

While both are borne on the same tree, male and female strobili are separate structures. Both are found near bud tips, and although a few branches can be found bearing both sexes, usually they are produced on separate branches. The southern pines tend to produce male flowers in the lower portions of the tree crown and females toward the top. Flower buds begin forming during the late summer and fall, and buds of both sexes are easily recognizable by January. We now have a few slides showing flower development through the receptive stage.

Our first slide shows a female flower bud before the bud scales have started to peel back. This is the best stage to isolate or bag the flower.

In our next slide the flower has developed further and the small conelet is beginning to emerge from the bud. If a flower is bagged later than this stage, there is much danger of contamination by loose pollen.

This slide shows the flower fully emerged from the bud and at maximum pollen receptivity. When looking at an actual flower in this stage, an opening between scales to the axis is visible to the naked eye. This is the optimum stage for pollination.

The next illustration is of male flowers or catkins at maturity, just prior to pollen shedding. This is the stage when collecting should be done.

Now catkins are at the height of pollen discharge.

Flowering of slash pine is the earliest of our major southern pines. Early stages of slash flowers are very evident shortly after Christmas and female flowers usually reach maximum receptivity during the last half of January or by the first week in February. Both loblolly and longleaf pines flower during late February or during the first two weeks in March, which is the reason for natural hybrid-Sonderegger pine. Shortleaf pine flowering, at least in Texas, occurs from mid-March into the first week of April. During some years there is a slight overlap of shortleaf and loblolly flowering.

Our next slide shows the female flower or conelet one year later. As you can see, it has not grown much. During this year the pollen has been growing toward the egg but fertilization has not yet occurred. During the second growing season the conelet starts to grow and fertilization finally takes place.

Pollen used in controlled pollination work is extracted from catkins collected at approximately the stage shown here. A simple test of pollen maturity is to squeeze a few catkins. If a thick

yellow curd comes from the catkins, they are at collection stage. However, if too green when picked, mold can cause trouble during extraction. By daily observation, catkins can be collected after a few have started to shed and extraction will be much simpler.

If a very slight contamination is allowable, catkins may be placed in extractors in the condition collected. To be certain of purity, however, catkins may be washed free of foreign pollen.

Pollen is best extracted in a warm room at low humidity. However, a balance must be struck between ease of extraction and low pollen viability for too much heat and too low humidity will kill the pollen. Small lots are easier to handle without molding or excessive drying. The next slide shows the component parts of a simple extraction assembly designed by Phil Wakeley and Tom Campbell: eight pound paper bag, wire cage for catkins, plastic funnels, voile screen, adhesive tape.

The next slide shows this extractor assembled.

Now the extractor is in position.

Another simple method for extracting small lots of pollen, originated by Mergen, is with sausage casings. The bag is stapled closed with catkins inside. When pollen has shed a hole is cut in one corner and the pollen is strained into vial for storage.

Pollen will retain a high percentage of viability at room temperature for only three to 14 days. For this reason, cold storage is essential if many species are to be crossed. This also explains, along with flowering dates, why so much of the earlier hybridization of southern pines was done on shortleaf pine. To work on slash pine, for example, with pollen of any of the other species, storage for almost a whole year is necessary. The Texas Forest Service has tested various storage conditions and has found storage in vials with cotton plugs in a cold room held at 35 to 37 degrees F. best. The next best storage condition was found in home refrigerators.

As it is fruitless to climb a tree several times to bag flowers and then pollinate them with dead pollen, it is advisable to test viability of all stored pollen. A very simple test, called the hanging drop slide method, gives a good indication of pollen viability. Materials needed are hanging drop slides having a depression in the middle portion, cover slips, sugar, vaseline, water and low power microscope. Mix a little pollen in five percent sucrose solution; put one drop of the mixture on slide cover slip; put vaseline around the depression on the slide; lay the slide on the cover slip; with the cover slip sticking to the vaseline, flip the slide and the drop hangs in the depression. The pollen in the slides should be incubated at room temperature, approximately 70 degrees F., 24 to 48 hours. Observe the slide under low power microscope or even a good hand lens. The percentage of pollen grains

germinating and producing pollen tubes is the indication of viability.

Now that we have collected and extracted pollen, stored it until needed and checked its viability, we are ready to start pollination. The material used to isolate female flowers must be porous and yet not open enough for loose pollen to get through. Workers in the South have found the canvas bags used on western species too heavy for our southern pines. Now widely used are synthetic sausage casings which allow enclosed branches to breath but cannot be penetrated by loose pollen. In this slide a bag is in place over female flowers. Needles are stripped off, the bag expanded and slipped over the branch and tied in place with wire twists. Cotton is placed around the branch at the point of tying, to close cracks. As indicated earlier, flowers are best bagged before the bud scales begin to peel back. We usually set an arbitrary limit of three flowers as a minimum for bagging on one branch and try to find branches with five or more flowers. It is very helpful to have a heavy copper wire with a brass hook brazed on the end for use in pulling limbs within reach and holding them there while working.

Numerous devices have been used for putting the desired pollen on female flowers when they reach the receptive stage. Sharp medicine droppers, hypodermic syringes with 16 gauge needles, and ear syringes with hypo needles are being used. The bag is punctured with the needle and a puff or two is usually sufficient to pollinate a bag if the pollen flows easily. The puncture is sealed with scotch tape.

After the flowers are well past the receptive stage as shown in the next slide, pollination bags are removed. A common practice is to slash them into shreds but leave the ripped bag tied to the branch. This serves as a flag to aid in relocating the conelets later. A long strip of durable cloth tied to the limb at this time also helps.

After the pollination bags are removed there is little to do except wait and hope. Squirrels, insects, disease, and wind damage are some of the hazards between pollination and cone collection 18 to 20 months later. A cloth bag placed over the conelets a year after pollination may help but we have had some injury following this practice. At least the bag prevents loss of seed if collection is delayed.

This has been a very hasty resumé of pine pollination procedures, and I know many points have been skipped or touched very lightly. If there are any questions, Mr. Allen and I will try to answer them.

17. SEED ORCHARDS FOR THE SOUTH[1/]

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The initial results of Forest Genetics research are in. They are sensational. Not so sensational as many promoters would lead us to expect but certainly striking enough so that the forestry profession would be very negligent if it failed to apply genetic principles in forest management.

Nearly every conceivable tree character of economic interest to forest industry is markedly influenced by inheritance. The work of Australian forest geneticists with slash and loblolly pine has shown that selection and breeding can produce three to five times as many trees of acceptable form and vigor as can be produced through random seed collection [2/].

Similarly, Monterey pine trees have been shown to differ inherently as much as five times in vigor, by as much as 20 percent in wood density. Fibril angle, fibre length, degree of knottiness, gum yield, disease resistance, and many other characters are rigidly controlled by the inheritance of a tree.

Simple selection of parent trees for superior form and vigor can produce seedlings with three times as many acceptable trees per acre when compared to seedlings from randomly selected parents.

Further research findings reveal that 17-year old seed orchards spaced at 80-100 trees per acre can produce 80 pounds of slash pine seed or 70 pounds of loblolly pine seed in a good seed year. At 13,000 seed per pound, this would be more than a million seeds per acre for slash pine, and at 22,000 seeds per pound this would be more than one and one-half million seeds per acre for loblolly pine. Twenty acres of seed orchard can supply seed for all of the planting needs of any industry. One hundred acres should take care of the state of Florida!

Even when genetic considerations are ignored, the economic advantages of collecting seed from a concentrated acreage which can be so managed as to avoid crop failures cannot be discounted. The tremendous and fantastically unsound practice of chasing all over the southeast to collect thousands of bushels of slash pine cones can be eliminated at a great saving.

1/ Because of the absence of the senior author, this paper was not read at the conference. The junior author, although handicapped by lack of both manuscript and slides, gave an excellent and spirited resume of the paper from memory. The paper as originally prepared is included here to make the record complete.

2/ Jim McWilliam, Queensland Forest Service, Queensland, Australia, in personal correspondence, 1953-1954.

Grafting techniques have been perfected here at the University of Florida and elsewhere whereby seed orchards bearing cones can be established within two years. However, it will probably be at least fifteen years from the date of establishment of the seed orchards before large quantities of cones are produced. Grafts made in July 1953 at the University of Florida produced seed this year and are bearing another crop of cones that will mature in the fall of 1955.

When factors of racial variation are taken into consideration it is conservative to estimate that 15-30 percent improvements in plantation productivity can be realized through using seed from orchards of selected trees.

As a primary part of the Forest Genetics Program, it is the aim of the School of Forestry to assist the wood using industries of the southeast in establishing orchards of selected trees which will eventually provide all of the tree seed used in forest planting.

Skilled laborers will be trained in the grafting and management of selected plants and will plan on making 5,000 or more grafts a year, about 50 percent of which may be expected to survive. These men will be able to produce selected plants far more efficiently than if each individual forest industry attempted to establish nursery facilities, lath houses, irrigation equipment, etc.

The grafts made by the University will be certified and shipped back to the cooperating industries for planting in their seed orchards. This certification will be important since eventually all tree seed sold for forest planting will probably require a certificate of genetic quality just as pedigrees are required in agriculture.

The biggest task will be that of selecting trees to be used in the seed orchards. Naturally two specialists cannot cover the southeast territory alone and locate enough trees to supply the needs of industry. The brunt of the selection task will fall to the cooperating industries. The following work plan offers one method whereby the job may be done.

Work Plan for Selecting Trees

Each cooperating industry will appoint a forester to the task of screening and selecting of plus trees[3] to be used in establishing the seed orchards. This assignment should not take more than a month of the appointee's time.

A representative from the University of Florida is visiting each cooperating industry this fall and winter and presenting lectures and demonstrations to the field foresters on the principles and methods of tree selection. A number of sample trees are actually selected and

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3/ Plus tree--a tree chosen because it is outstanding when compared to other trees.

through discussion the foresters gain a clear picture of the kinds of trees that should be searched for. The response to these demonstrations has been enthusiastic and in every case the foresters have indicated that they benefited greatly from the demonstrations. The importance of field illustration and discussion cannot be over-emphasized. Most of the foresters in the field have had little or no genetic training and do not know what to look for until shown.

After the lecture and demonstration each cooperating forester has as part of his regular work assignment the task of locating the best tree he sees each day. At the end of the week the best tree among these four or five will be reported to the contact forester in charge of the general selection program. These will be further screened by the contact forester. Special incentives are being offered by industry to encourage the recording of trees by the woods crews. One industry is offering a bottle of whiskey for the best tree recorded each week.

The number of trees needed for each industry will depend on the size of its holdings and the number of seedlings it plants. The more trees recorded the more rigorous final selections can be. In theory the International Paper Company should record close to 6,000 trees by January 1955. From these they will select about 300 to 500 trees for their seed orchards. Over 300 foresters have attended the special lectures and demonstrations. From them and their employees we can expect a thorough screening of our woods for outstanding trees.

During the fall and winter of 1955 a University representative will spend another week with the cooperating industry, examining the selected trees and making final selections. We will begin grafting in the summer of 1955 and by the winter of 1956 each cooperator should have at least one and one-half acres of seed orchard established. By 1958 each cooperating industry will have five to ten acres of seed orchard.

A few grafts from each selected tree will be held for research purposes. As soon as the seed orchard begins to produce seed we will begin progeny testing. Any trees that do not produce desirable seedlings will be rogued from the seed orchard. Further selection and breeding amongst trees of proven genetic superiority, as shown by progeny tests, will provide further improvement in planting productivity. Constant search in the woods will uncover trees superior to our initial selections.

As with corn and other agricultural crops, selection, breeding, reselection, and improvement will be continuous from one year to the next.

Eventually as the pure service job of selection and grafting becomes more onerous and industry is convinced of the merits of seed orchards, the University of Florida may be justified in employing further personnel who will be free to devote their full energies to this important work.

Along with completing a job of considerable importance to our economy, the establishment of these seed orchards will provide excellent material for further research. Material from these selected trees will be made freely available to all research agencies interested in tree improvement.

18. STIMULATING SEED PRODUCTION BY FERTILIZATION AND GIRDLING

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Within the past two decades, the advent of tree improvement activities on practically a world-wide scale has aroused increasingly greater interest and effort in stimulating fecundity of forest trees. Various methods have been employed in attempts to achieve greater seed production. Two of these methods, loosely termed "fertilization" and "girdling", will be discussed here.

Fertilization, or simply the application of fertilizers, has long been a standard horticultural practice for improving the fruitfulness of orchards. In forestry, experience with fertilizers is very limited but there have been sufficient trials to indicate real potentialities. Paul and Marts (1931) in a study of summer wood production in longleaf pine in a deep sand region of Florida applied up to 19,058 pounds per acre (270 pounds per tree) of nitrate of soda and sulphate of ammonia, plus 245 pounds of superphosphate and 189 pounds of potassium sulphate per tree, alone and in combination with mulching, watering, or both, over a 3-year period. Four years after initial application, incidental counts of cone production showed that the average number of cones on check trees was only two; on mulched trees, 11; on trees supplied with sodium nitrate, 16; on irrigated trees, 25; on trees receiving sodium nitrate and irrigation, 54; and on trees irrigated and given an application of a complete fertilizer, 62. The improvement brought about by the joint treatments is worth noting.

Chandler (1938) found that heavy additions of sodium nitrate and ammonium sulphate increased the yield of seed for both beech and sugar maple, and also increased the viability of maple seed. Detwiler (1943) accidentally applied a heroic dosage of 14,000 pounds per acre of a 10-5-4 mix to a 23-inch white oak tree in Alexandria, Virginia, and observed that the acorn production jumped from the "normal" of two bushels to eight bushels after about 18 months following application. Wenger (1953) reported the results of a formal experiment undertaken by Pomeroy near Franklin, Virginia, and involving, among other treatments, the use of fertilizers to stimulate seed production in loblolly

pine. The dosage per tree was either twenty-five or fifty pounds of a 7-7-7 mix. Cone production of 25-year-old trees, averaging 12.6 inches in d.b.h., increased about three times over that of check trees in the third season after application, but in 40-year-old trees, averaging 14.7 inches in d.b.h., cone production failed to increase significantly. Wenger postulated that the amount of fertilizer was not sufficient to produce a response in the older trees; he also found that in the younger trees there was no significant difference between light and heavy fertilizing, the number of cones per tree averaging 36 for checks, 98 for the 25 pound rate, and 123 for the 50 pound rate.

Allen (1953) reported on preliminary results of fertilizing and releasing longleaf pine in South Mississippi and South Alabama, where eight-inch trees were given a dosage of 19 pounds of a 5-15-5 mix, 10-inch trees 30 pounds, and 12-inch trees 44 pounds of the same mix. Three years after treatment, the treated trees produced 12 times more cones than the untreated ones (check trees bearing 1.8 cones per tree), and in the fourth year four times more cones than the check trees which averaged only 0.9 cones per tree. The two-year average cone production actually was 1.3 cones per check treatment, 6.9 per release, 13.5 per fertilized, and 16.7 per fertilized and released. Allen pointed out that size of tree appeared to be important, eight-inch trees yielding only 4.6 cones, but 10-inch trees bearing 10.3 cones, and 12-inch trees bearing 13.9 cones. Of perhaps greater significance was the finding that three years after treatment trees bearing cones in a good seed year were more than three times as fruitful as those trees that bore no cones at time of treatment, the actual values being 14.7 cones per tree versus 4.5 cones, respectively. Grano (1951) emphasized this point also with his data on pines in South Arkansas where 90 percent of trees having cones in 1949 bore cones also in 1951, averaging 129 per tree, while 70 percent of the trees with no cones in 1949 had cones in 1951, but averaged only 37 cones per tree. Similarly, Wenger (1953) showed that the fecundity of loblolly in southeast Virginia, after release, was directly related to fruitfulness before release, the ratios for three levels being 10:37, 30:80, and 50:124, respectively.

These instances will perhaps suffice as evidence that fertilizing of forest trees will stimulate seed production, but the results of these, as well as other studies, are too variable to permit formulating any clear-cut prescriptions. To some extent, fertilizing will continue to be somewhat of a local matter, depending on soils, climate, species, age of tree, and other specific factors. However, many general principles can doubtless be worked out after more experience has been gained and critical evaluation of dosages, salt combinations, seasons of application, placement tests, and other treatments have been made.

Let us now consider, briefly, the practice of "girdling" or, perhaps more appropriately, ringing, as well as of banding, or strangulation, as methods of improving the fecundity of forest trees. Again, horticulturists began employing these practices years ago, often with good results. Recent interest in these practices among foresters has, doubtless, been intensified by the appearance in 1948 of English translation of Bertil Lindquist's book entitled "Genetics in Swedish Forestry Practice".

The immediate objective of girdling is to retard or interrupt sap movement, thus retarding water and salt flow from the roots upward, and the flow of elaborated foods or photosynthates from the leaves to the roots. If girdling is complete and thorough the tree should die within five years, depending on the species, size, or age. The purpose of "girdling" in seed stimulation work is not to kill the tree but to bring about certain changes in carbohydrate metabolism and salt mobilization which are believed to aid either flower formation, fruit setting, or both.

The effects of "girdling" or ringing have been observed in a number of investigations on forest trees. For example, Baldwin (1934) found abnormally large quantities of sugars trapped above the girdle during the first season following the operation, but at the end of the second season sugar reserves had fallen lower than in the trees not girdled. Stefansson (1948) applied strangulation to young Scots pines and Norway spruce in an attempt to induce increased seed production. He found marked stimulation of flowers, mainly male ones, two to three seasons after the operation was begun. Strangled older trees (40 to 70 years) took longer to respond, and the response was not strong. Ring-barking, leaving at least two inches of bark intact, and root pruning at least one meter from the tree, produced effects that were clearly detectable after three seasons. Stefansson concluded that in older conifers strangulation is perhaps not worthwhile, but that ringing and the addition of phosphate fertilizer might be a desirable practice. Holmes and Matthews (1951) compared girdling and banding in a 20-year old plantation of Corsican pine. Stem girdling in the form of a continuous knife incision at breast height gave the best results which showed up in the second season after treatment. Girdling was more effective on larger trees. Two semicircular cuts caused the heaviest swelling, and metal bands the least. In general, metal bands produced lower cone yields than did other treatments. Girdling was found to be most effective in May, least effective in January.

Wenger's (1953) report on fertilizing of loblolly pine also includes results of some comparisons on the effectiveness of girdling. In the main experiment the girdle consisted of a knife cut halfway around the stem and three feet above the ground. The knife cut wound made in late April had completely closed by June of the first season, and the lack of response from this treatment was attributed to the rapid healing of the "girdle". A small side experiment was installed in 1947, taking a 1/4-inch strip of bark halfway around the stem. This strip was wide enough to remain open through the following season, sufficient to significantly increase cone production the following year, with 53 cones per "girdled" tree against 15 cones per check tree.

Vincent (1940) in Czechoslovakia carried out partial girdling and complete girdling, either at the breast height point or just below the crown, on both pine and spruce. In no instance did he find any increased seed production in treated trees, compared to equally vigorous trees not girdled. He concluded that satisfactory seed production

in timber stands can best be assured by repeated heavy thinnings beginning at least 20 years in advance of the needs for abundant seed supply.

These and other records of girdling, or ringing, and strangulation, or banding, indicate something of the nature and magnitude of response that may be expected. Generally speaking, these practices tend to reduce the vigor of the tree, seeming, therefore, less desirable than fertilizing, irrigation, release, and other practices which usually improve tree vigor and growth. Be that as it may, it seems important at this stage to avoid condemning any of these practices until additional experience and study provide a broader basis for more sound conclusions.

Since forestry investigations on both fertilizing and ringing have been generally of more or less empiric nature, we may find it worthwhile to review some of the principles that horticulturists have developed over the years. The work of Kraus and Kraybill (1918) nearly four decades ago focused attention of horticulturist on the practicability of employing some of the basic knowledge of carbohydrate and nitrogen mobilization in fertilizing and other practices for improving fruit production. Kraus and Kraybill were the first to supply chemical data demonstrating the relationships between fruiting response and carbohydrate and nitrogen levels in the plant. In their early work, primarily concerned with the fruit setting in tomatoes, they were careful to point out that the processes involved in fruit setting were not necessarily the same as those involved in flower formation.

These differences can be more clearly brought out by considering the main environmental factors that affect flower-bud differentiation in contrast to those affecting fruit setting. Following are the main factors affecting flower-bud differentiation:

1. Light intensity: In the interior of the crown, light intensity may be as low as 500 foot-candles, a value too low for flower-bud differentiation.

2. Duration of light: Extremely important with many fruit species. Photo-period may also be important with forest trees.

3. Ringing
   a. Trees with stone fruits are frequently injured by ringing.
   b. Poor vigor trees are likewise injured.
   c. Very young trees and small limbs are usually not responsive to ringing.
   d. For "alternate" bearing species, ringing in "off" years is of no avail.

   e. Timing is important. Ringing should be done three to five weeks before floral differentiation which occurs usually in early summer.

4. Root pruning: Has often been effective. Must be done a few weeks before floral primordia differentiate.

5. Defloration: Complete defloration usually results in abundant differentiation of floral primordia for the succeeding year's crop.

6. Bending: Pulling upright branches to a horizontal or downward position usually causes flower buds to form.

7. Defoliation: Usually bad; prevents differentiation of flower buds.

8. Growth regulators, acetylene, and ethylene: Very effective on some plants.

9. Water supply: Continuous reduction of soil water during the period in which flowers are differentiated produces intensely stimulating effect on flower formation.

10. Effect of nitrogen application: Fertilizing with organic manures (like chicken and pig manure) definitely delays flower formation in young bearing trees. Trees low in vigor may be benefited. Late summer applications may be most helpful by delaying leaf-fall and permitting carbohydrate accumulation.

11. Pruning: Delays flower formation on young non-bearing trees.

12. Sprays: Usually reduce flower formation; possibly interfere with photosynthesis.

Among the factors that affect fruit setting are:

1. Nutrients: Nitrogen is frequently most limiting; should be so timed as to become available after flowers are formed and fruit are ready to set.

2. Water: Lack of water may cause abscission of immature fruit.

3. Pruning: Light to moderate pruning is beneficial, reducing excessive competition between flowers.

4. Ringing: Has variable effect; should not be done later than blooming.

5. Carbohydrate-nitrogen relationships: Excessively rapid rate of amino acid synthesis induced by large amounts of inorganic nitrogen results in rapid vegetative growth, with little carbohydrate material left for development of sex organs to functional condition, hence may prevent fertilization. In such situations, supplementary light will cause fruit to set.

6. Competition between flower and fruit: May occur even in vigorous bearing trees.

7. Ecological factors: Temperature, wind, humidity, rain, etc., may, obviously, interfere with pollination, fertilization, and subsequent development.

8. Fungal and insect attack.

9. Spray materials.

It is evident from this listing, that not even common factors, such as water supply and nutrient salts, necessarily affect flower bud formation in the same manner, degree, or both, as they affect fruit setting. Variable results in experiments involving repeated treatments could well stem from possible carry-over effects or timing effects that influence flower bud differentiation in one instance and fruit setting in another.

In the future, fertilizing, "girdling," or both, for stimulating seed production in forest trees, may become a routine practice particularly in the development of seed orchards. If so, it will be important to fully consider the requirements of both flower bud differentiation and fruit setting. In addition, it is well to remember, that neither fertilizing nor "girdling" has so far shown much promise for stimulating abundant seed production in very young trees.

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19. RESULTS FROM WESTVACO SEED PRODUCTION AREAS THROUGH 1954[1/]

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At the Atlanta Forest Tree Improvement Conference in January 1953 it was my privilege to give a short paper on Westvaco seed production areas setting forth the methods of selecting the trees and collecting and handling the cones and seed. This paper deals with cone and seed yields from our 1953 and 1954 seed production areas and the cost of the seed produced.

In September 1953 we collected 105 bushels of cones from 74 trees in our first loblolly pine seed production area. This amounted to 1.44 bushels per tree. These cones yielded 115 pounds of double winnowed clean seed--17.5 ounces of seed per bushel of cones. Cutting tests showed 85 percent sound seed. Seed counts averaged 18,100 seeds per pound. Cone counts ranged from 225 to 300 per bushel and cones

1/ Read by R. O. Gustafson, Westvaco Experimental Forest, in the author's absence.

weighed 28 to 31 pounds per bushel at the time of collection. Seedlings from this seed lot will be planted on Company lands this winter.

This past fall we cut the remaining 31 trees on the first seed production area and they yielded a much smaller average volume of cones--only 1/2 bushel per tree. These trees had been left standing the previous year because we could only handle about 100 bushels of cones at that time. In general they were the trees with the poorer crop of cones in 1953. This past fall--four seasons after release--again these trees had a poor crop of cones.

Last October 60 trees cut from our 1954 seed production area yielded 99-1/2 bushels of cones--an average of 1.66 bushels per tree. The cones turned out 116.5 pounds of double winnowed clean seed--18.7 ounces per bushel of cones. Cones averaged 330 per bushel. Collection cost was $2.02 per bushel. To this must be added $0.58 per bushel for extracting plus $0.21 per bushel for tree selection making a total of $2.81 per bushel of cones, or $2.39 per pound of clean seed.

In addition to the 99-1/2 bushels from the 1954 seed production area we collected 83 bushels from the remnants of the 1953 area and from scattered seed trees left in harvest cuts at the same time in the same general area. This lot of cones from 78 trees averaged 1.06 bushels per tree and yielded 104.5 pounds of clean seed--20.1 ounces of seed per bushel of cones. Collection costs were $2.68 per bushel--$0.66 per bushel higher than from the 1954 seed production area. Seed extraction cost $0.58 per bushel and tree selection $0.33 per bushel--a total of $3.59 per bushel of cones, or $2.85 per pound of clean seed.

The cost figures given are based on $1.08 per hour for labor with a foreman at $1.41. A breakdown of collection costs shows 70 percent for labor, 11 percent for transportation, and 19 percent for overhead. Included in the extraction cost is a charge of $0.25 per bushel for depreciation on equipment and buildings. Tree selection cost $0.35 per tree. Cone and seed yields and seed costs are summarized in Table 1.

Table 1. Cone and Seed Yields and Cost of Seed from 1953 and 1954 Production Areas

Area	Number of Trees	Cone Yield Bushels	Bushels per Tree	Pounds Clean Seed	Seed per Bushel of Cones ounces	Seed Cost per Pound
1953	74	105	1.44	115	17.5	$ -----
1954	60	99.5	1.66	116.5	18.7	2.39
1/ 1954	78	83	1.06	104.5	20.1	2.85

1/ From scattered seed trees and remnants of 1953 area.

This fall we also collected 2-1/2 bushels of slash pine from our 23-year-old slash pine seed production area, and several small lots of seed from high density trees.

In addition to the Experimental Forest's collection of cones our Company's Southern Woodlands Department collected 868 bushels of Coastal Plain loblolly, 110 bushels of Piedmont loblolly and 110 bushels of Colleton County, South Carolina slash pine. The State Forest Service extracted the seed from the 868 bushels and Westvaco extracted the seed from the two small lots.

Total collection of cones this year for West Virginia Pulp and Paper Company seed to be planted at the State Nursery was 1,160 bushels of loblolly and 110 bushels of slash pine. Southern Woodlands collections were made from seed trees left to re-seed cut-over areas. In 1956 Southern Woodlands' seed production areas will come into production.

The Experimental Forest now has 55 acres of loblolly pine seed production area containing 608 trees as well as 18 acres of slash pine seed production area containing 520 trees. Our Company's Southern Woodlands Department has 37 acres of loblolly pine seed production area containing 494 trees and 18 acres of slash pine seed production area containing 520 trees. This is a total for West Virginia Pulp and Paper Company of 92 acres of loblolly pine and 36 acres of slash pine aggregating 2,142 selected seed production trees. We plan to add another 100 acres this winter.

From 1956 on we expect to furnish from selected parent trees all the seed for our loblolly pine planting stock. This is a feasible and financially sound program. West Virginia Pulp and Paper Company for one considers it a first step in the improvement of our Southern pine forests.

Hoy C. Grigsby and Charles T. Shotts of the Mississippi Forestry Commission concluded the afternoon session by showing the Commission's 18-minute color film, "Developing Pedigreed Trees".

Dr. Bruce Zobel's talk describing his 1954 trip to Mexico to collect seed of Mexican pine, scheduled for the night session was given at an informal meeting in his hotel. His talk was illustrated by kodachrome slides.

Morning Session, January 6
Moderator, Dr. Scott S. Pauley

20. GRAFTING TECHNIQUES USED IN PROPAGATING SPECIES OF PINE IN THE SOUTHEAST FOR EXPERIMENTAL AND SEED ORCHARD USE

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The recent upsurge in forest tree improvement and genetics in the Southeast and elsewhere in the United States has made necessary better methods of vegetative propagation. Although only a tool of the forest geneticist, vegetative propagation, either by grafting or by the rooting of cuttings, is an important aid in carrying out effective studies in a reasonable time. Without these techniques his work would be considerably hampered.

Both the rooting of cuttings and the grafting of scion shoots have their place in these programs. For many purposes, however, rooting is more desirable than grafting especially where root systems genetically identical to the parent tree are required. The more widespread use of grafting is of course due in large part to the better success generally associated with this method.

Unfortunately rooting becomes increasingly more difficult with material from older trees. A high percentage of cuttings from young trees may root but only a few or none at all from trees beyond 10 years of age. Grafting, on the other hand, does not share this age limitation. Trees from seedlings to mature individuals can be readily grafted provided, of course, that vigorous tissue is available. If necessary, vigor of old valuable trees can be improved considerably by preparatory fertilizing and even by watering.

This difference in success of grafting and rooting associated with the age of the tree can be graphically illustrated by work on shortleaf pine in connection with the littleleaf disease. Trees ranging in age from 30 to 81 years have been propagated successfully by grafting. In several cases 90 percent success has been attained. Ten out of 10 grafts were successful using scion material from one 81-year-old tree.

However, attempts at rooting cuttings from many of these same trees have been unsuccessful. In the selection and breeding work aimed at developing littleleaf resistant shortleaf pine an effective rooting technique is sorely needed. The resistance which we seek must be found in the root system of the tree. It must be a resistance

to a combination of factors involving a soil fungus, poor soil aeration, and generally poor site conditions. Only the rooting of cuttings can provide root systems genetically identical to the selected tree for testing under controlled conditions. Several large-scale attempts have been made to root this species. In a recent experiment cuttings were collected from 3- and 4-year-old seedlings and from three 35-year-old trees every three weeks from August to March. Only 16 percent of the seedling material rooted. Only eight percent of the cuttings from one mature tree rooted.

Work by Chase and Galle, Mergen, and Zobel in the Southeast indicates that grafting is a practical technique for propagating vegetatively many species of pine. In many instances it is used in preference to rooting simply because it works well.

Grafting on its own merits has many important applications in tree improvement and genetics work. Zobel's study of the inheritance of wood specific gravity in loblolly pine is an example. He grafted scion twigs from trees having different wood densities onto a single rootstock. If, after several years, the newly developed woods of the different scions have the same density then it can be said that environment is partially, or wholly, in control of this important characteristic. On the other hand, should the specific gravity of the wood in each scion remain unchanged then it can be said with good certainty that wood density is inherited. This same technique can be employed in determining the inheritance of other anatomical and physiological characteristics of selected material.

Another good example is the inducement of early flowering of seedling tissue by grafting it into the crown of a mature tree. Or young material may possibly flower early when grafted upon stock of different species or even genera.

A large share of the grafting of forest trees today, and in the future, concerns the establishment of seed orchards. This technique has been used successfully for many years by horticulturists in developing fruit and nut orchards. Rooted cuttings have seldom been used principally because grafting is simpler and generally more successful. Then too, grafting allowed the use of rootstocks of other varieties or species resistant to various soil-inhabiting pests or adapted to certain site conditions.

Seed orchards in Europe, Australia, and the United States are being started with grafted trees. Both greenhouse and field grafting is being employed. Mergen and others have shown that the bottle graft is suitable for direct grafting in the field using previously established seedlings as stock. In greenhouse grafting, with the maintenance of a high relative humidity, the side, veneer, and related grafts can be used with good results.

A type of graft not used too often may be well suited for seed orchard work especially for the enlargement or expansion of the orchard. It is the soft or succulent tissue graft. Actually it is merely a variation of the common cleft graft where very young shoots are used as scion material. The technique is quite simple and the results generally excellent. Small scale tests at Athens have been 60 to 70 percent successful. Good results were had in making the following intra- and inter-specific grafts:

Shortleaf on shortleaf
Loblolly on loblolly
Loblolly on shortleaf
Shortleaf on loblolly
Slash on loblolly
Slash on shortleaf
Loblolly on Virginia
Shortleaf on Virginia
Eastern White Pine on Virginia

Most of these grafts were made outdoors under shade. In making the graft, succulent scion shoots with needles only slightly developed were cleft-grafted into the succulent shoot of the stock seedling. Only about an inch-long scion shoot was used. A corresponding length of the growing tip of the stock tree was removed and the cleft cut made. Unlike most other grafting methods the shock upon the stock plant is of no consequence since only a small bit of tissue is removed. Very little, if any, pruning is done later. No great care was exercised in inserting the wedge-shaped base of the scion into the cleft cut of the stock. Likewise little effort was made to align the cambial zones. Fusion appeared to proceed rapidly. Very likely a high proportion of tissue other than the cambium may become meristematic in such young stems and so effect a quick joining. The rapid healing which does occur certainly must be aided by the intact crown of the stock seedling. Adequate food can thus be manufactured by the plant to maintain a high rate of tissue formation.

After the scion was inserted into the stock stem the graft was firmly wrapped with a soft cotton thread. Instead of tying the thread it was found expedient to merely smear a small bit of soft grafting wax along one side of this wrapping. This prevented unravelling and held the graft firmly. The upper portion of the stock tree including the newly grafted scion was then enclosed in a 2-pound cellophane bag having a few small holes for aeration. Transpiration from the enclosed foliage quickly raised the humidity within and thus prevented wilting of the scion. The completed graft was then placed under a light unbroken shade. After three weeks the bag was partially cut open to reduce the humidity. The following week it was completely removed and the tree placed in the lath house. A month later it was moved into the open.

At first the method seems difficult because of the small stems and the delicate tissues involved. Actually it was found that more grafts of this type could be made per hour than either the conventional side, veneer, or bottle grafts.

Work during the past summer suggests that soft tissue grafting can be successfully done throughout most of the growing season. Equally good results were obtained in early spring, in mid and in late summer. Some of the grafting was done when air temperatures ranged near 95°F., with no apparent adverse effects.

An important problem associated with this method concerns the availability, transportation, and storage of scion material. On large vigorous trees the young shoots may be too large and thick for use with this method. This difficulty can be overcome by different forms of pruning to stimulate the development of epicormic and needle bundle shoots. Such treatment can possibly be applied successfully to shortleaf and loblolly pine by making the pruning three or four weeks before the material is needed. Tip moth damage on small trees of these species often results in an abundance of suitable shoots. Such shoots have been observed in the crowns of adult shortleaf pine where tip moth or some other agency has destroyed the bud or tip of the stem. Further work will be done during the coming summer to find ways of stimulating desirable scion material in the crowns of mature shortleaf, loblolly, and slash pines.

This method of grafting possibly will find its greatest use in expanding or multiplying the existing clones already in a seed orchard. After one or two years in the orchard grafted trees will have sufficient crown to provide the necessary scion material. Very light pruning or even tip moth damage will encourage the development of suitable shoots. Each such small tree should be capable of supplying 10 or 15 shoots without harm to the tree. Thus, from a clone of 10 trees we might obtain as many as 150 scion shoots for grafting.

The transportation and storage of scion material should not be a problem when this method is used for seed orchard expansion. All work will be done on the same area using established seedling stock. It will, of course, be necessary to maintain these succulent shoots in a turgid condition at all times from the time of removal from the scion tree until the new graft is firmly joined and established. A small container filled with moist sphagnum moss can be used to carry the material from tree to tree. After the cellophane bag is placed over the completed graft it will be necessary to provide shade to prevent heat build-up within. This means an individual shade for each grafted tree. Possibly an inverted paper bag stapled on a slat will serve the purpose. Other devices will be tried during the coming summer.

Recently the state of Georgia has embarked upon an ambitious project--that of establishing seed orchards of loblolly and slash

pine. The Georgia Forestry Commission in cooperation with the Southeastern Forest Experiment Station has developed plans aimed at the eventual establishment of several hundred acres of grafted trees. Scion material from selected individuals having good seed-bearing ability, apparent resistance to fusiform rust, and with good growth and form characteristics will be used. Progeny tests of the selected trees will be carried on concurrently under another project.

Over 2,500 seedlings will be grafted early in 1955 using scion material from as many as 50 selected trees. This grafting will be done in a humidified greenhouse using the side and veneer grafts. Early in the spring and throughout the summer various forms of field grafting will be tried. These will include the bottle, soft tissue, and other grafts. It is hoped that in 1956 all grafting can be done in the open on seedlings outplanted in the orchard. The different grafted clones will be considerably expanded within each area through the use of soft tissue grafts.

A spacing of 16 x 16 feet is contemplated allowing 170 grafted trees per acre. One-year-old seedlings were outplanted on the areas this past fall--two at each "spot". Both will be grafted with the hope that one of the two grafts will be successful. The duplicate seedling will be removed. If both fail they will be regrafted later in the season. This work is in large part experimental in an effort to develop suitable techniques for large scale use.

Tip moth damage to grafted trees may be a serious problem in the management of these orchards. During the first year after grafting heavy infestations may badly stunt the tree or even kill it. For the next few years, the damage may be slight or even beneficial by encouraging the development of a thick crown. Actually, this will be done by artificial pruning so as to produce a squatty and full-crowned tree. The greatest damage, if this pest is not controlled, may come when the grafted trees begin flowering. A late fall or early spring infestation of the buds containing embryonic female flowers would mean a poor seed crop two years hence.

Grafting, or more specifically pine grafting, has found considerable use in the overlapping fields of forest tree improvement and genetics. Workers in these phases of forestry have and will continue to use this technique of vegetative propagation in research and in practical applications. Together with methods of rooting, grafting will allow us to take advantage of shortcuts so much sought after in this work. We certainly can expect earlier results as these tools of the forest geneticist are further improved and perfected.

There still are many problems confronting the casual use of this technique with southern pine species. Difficult forms of grafting, such as the needle bundle graft, must be developed in order that desirable seedlings can be propagated vegetatively without destroying the original plant. Cheaper methods of propagating by

grafting are also essential. This will probably come as large scale seed orchard grafting is put to greater use.

(This paper was illustrated with kodachrome slides.)

21. ROOTING AND GRAFTING OF SLASH PINE[1]

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Asexual propagation is an important phase in a forest tree improvement program. In the forest genetics program with slash and longleaf pines at Lake City, Florida, this method has been used to multiply and perpetuate desirable germ plasm, estimate the genotype of selected trees, induce early flowering, and establish seed orchards for superior forest tree seed. In this report, I hope to give you a thumbnail sketch of some of the problems we were confronted with, report on the results of our experiments, and describe workable rooting and grafting methods which have been field tested.

At first I would like to talk about vegetative propagation by rooting.

Type of Cutting

Our findings with slash pine cuttings on the effect of age of tree on rooting are in agreement with those of other species. More than 90 percent of slash pine cuttings from very young trees root but cuttings collected from older trees root poorly and with much difficulty. The dividing line between extensive rooting and poor rooting lies between 2-year-old trees and 3-year-old trees.

Season of Collection

The first studies with slash pine cuttings were conducted in outdoor propagation beds. Since 1943, about all of the experiments were carried out in the greenhouse during the fall and winter months for lack of environmental control during the summer in both greenhouse and field. Effect of season of collection on the ability to survive in the propagation beds was quite varied. In one experiment cuttings were collected during the period from August till December.

1/ The work described in this report was carried out at the Lake City, Florida, Research Center of the Southeastern Forest Experiment Station, while the author was in charge of its forest tree improvement program.

At the beginning of the dormant stage survival was low but increased steadily until the middle of November when a sharp drop occurred. Cuttings collected in the early part of February started growth shortly after they were planted in the warm propagation beds. From this it appears that late October and early November is the best time to collect the slash pine cuttings.

One difficulty with these experiments is the fact that season and environment in the greenhouse are confounded. This makes it difficult to isolate either factor.

Treatment

Cuttings have been prepared in a number of ways, but no method of physical treatment was superior to that of planting the cuttings right after removal from the tree. Etiolating the shoots prior to their removal from the tree, along with wounding the base, gave poor results. With some species, etiolation is beneficial. When strips of brown paper were wrapped around the upper part of the shoot, the overall effect was depressing. It lowered the starch content within the cuttings and the tight paper wrap provided poor aeration around the needles.

Good response was recorded when the basal parts of the cuttings were wounded before they were treated with chemicals. This resulted in a well-developed root system on some of the cuttings.

Storing the cuttings for a few weeks in a pre-callusing box prior to chemical treatment is beneficial with some plants but it was found undesirable for slash pine. On most of the cuttings which were stored in sphagnum moss at 82° F. for a two-week period callus had started to form at the base. Callus growth, however, did not cover the entire bases and the fungi destroyed the parenchymatous tissue around the base and subsequent survival of these cuttings was poor.

Several of the most promising growth regulators were used in conjunction with vitamins and sucrose. Up till now over 300 different treatments have been tested. Various methods of application were tested, including treatment under vacuum. Past results with cuttings from mature slash pine trees have not definitely established the beneficial effect of chemical treatments. None of the treatments or treatment combinations gave consistently better results; many times results in the following years contradicted conclusions of the earlier studies. Cuttings have rooted under more than 50 types of treatments. These conditions ranged from no treatment to the most complex chemical treatment with growth regulators, vitamins, nutrients, sugar, and fungicide. However, chemical treatment of slash pine cuttings from very young plants was beneficial. Supplementing the nutritional level in the cuttings, by spraying the foliage with nutrients and sucrose, had a depressing effect. This treatment favored a large-number of fungi

which destroyed the meristematic tissue of the cuttings.

Throughout the experiments with cuttings, the detrimental effects of microorganisms was evident. Applications of ferbam, streptomycin, santobrite, or Phygon XL to the propagation beds helped to check fungal activities.

Slash pine cuttings require a humid environment during the rooting period. Best results were obtained when cuttings were sprayed at eight to 10-minute intervals during the daylight hours. Neither placing the cuttings with their bases in water, nor the use of a closed propagation frame was suitable for rooting. When the bases were submerged, they rooted as a result of poor aeration. Closed propagation frames in which the sand medium was kept moist at all times and where the foliage was sprayed daily with water were a complete failure. The needles dried out within a few weeks after collection. When cuttings are rooted in open propagation beds and sprayed intermittently, direct insolation had a detrimental effect on survival, but good results were obtained in shaded beds.

Addition of vermiculite to a sand rooting medium increased the average level of rooting. Of 15 rooting media tested, a 50-50 mixture of sand and vermiculite proved to be best. Apparently good aeration along with adequate moisture-holding capacity are necessary characteristics of a good rooting medium. The medium was maintained at a temperature between 80° to 85° F.

Air-Layering

One of the important factors which contribute to the failure of root development in slash pine cuttings is the shock which the cuttings sustain when they are removed from the tree. A large amount of reserve carbohydrates and other nutrients are needed to form the callus tissue and to develop the roots. Once a cutting is severed from the tree, no further nutrients can be translocated from the stem to the cutting. Then the cutting has to rely on the nutrients stored before it was severed. In air-layering on the other hand, roots are induced to form on the branches while they are still a part of the parent plant. Although no previous attempt to air-layer pine trees in America was reported it was felt that this method might bring about the production of rooted material from the refractory species which are difficult to propagate by cuttings.

In our experiment where sphagnum moss was used as rooting material and a polyethylene film as wrapping material the effects of time of application and effect of indolebutyric acid were studied. To study the effects of indolebutyric acid treatment, two branches growing from the same whorl were used. The environmental conditions for the two groups were equivalent except for the factor specifically under test.

The results on adventitious root induction are presented in this table where the data have been assembled by time of year and by chemical treatment. The time span for the first root formation is also given. The average number of roots developed for all attempts, including the unrooted branches, was 5.58 for the treated branches whereas only 1.46 were produced by the untreated air-layers. The difference between the number of branches which rooted and number of roots produced per rooted branch indicated a beneficial effect of chemical treatment which was significant at the one percent level. Average rooting percentage was 84.6 for the treated branches whereas only 50.0 percent of the untreated branches rooted. The same chemical treatment was lethal when it was used on slash pine cuttings. The branches which were air-layered during October produced the first roots after 23 weeks. These branches became semi-dormant soon after girdling and root initiation probably took place at the start of the next growing season.

From our experience with slash pine we found that the best time to apply the air-layers is during May, June, and July. Sturdy, vigorous, straight shoots in the upper part of the crown should be selected. Before making the girdle, the needles are stripped for a distance of about eight-inches. The best place to prepare the girdle is some 10-inches from the tip of the branch, preferably in the current year's growth. On very vigorous shoots of trees below 10-years of age a one-inch girdle should be used. On older trees a 1/2-inch girdle will be satisfactory. Be sure that all the bark and cambium is removed. The best results were obtained when a 1.2 percent mixture of indolebutyric acid in talcum powder was used as a rooting powder. The upper rim of the girdle should be treated with a liberal dose of the powder. We found that the indolebutyric acid treatment stimulated the formation of well-balanced root systems.

As a rooting medium, moist sphagnum moss was used. When the sphagnum moss was collected in a dry state we soaked it in water for several hours before using. Excess water was squeezed out. After a handfull of moist sphagnum moss is packed around the treated girdle, the air-layer is covered with a plastic sheet, 9 by 10 inches in size. Commercially available air-layering sheets gave very satisfactory results. When successful, the roots will form within six to eight weeks, but the marcotte should be left on the tree for at least 12 weeks so that the roots become firmer and develop side branches. The white root tips will become visible through the plastic wrapping. After the roots are well formed, the branch is clipped off about four to five inches below the girdle, and is potted in loose soil and kept shaded during the initial period. The new plant needs frequent watering. Also, fertilizing with a soluble fertilizer will stimulate active root growth. Potted plants can be outplanted into the field after roots are well developed.

Besides being able to take advantage of beneficial effects of chemicals, air-layers can be obtained without the use of extensive physical installations. Also, air-layered branches in general have a better balanced root system than cuttings.

Grafting

Another method to propagate plants asexually is by grafting. various types and modifications of standard horticultural grafting methods have been tried with pines. It appears that special techniques have to be developed for the various species occurring in different climatic regions. A study was devised with dormant slash pine scions to determine the limiting factors. Three types of grafts--cleft graft, veneer graft, and bottle grafts--were kept under four environmental conditions. Greenhouse-open bench, greenhouse sweatbox, field-partial overhead shade, and field-partial overhead shade covered by individual humidity chambers.

Best overall results were obtained with bottle grafts (Figure 1).

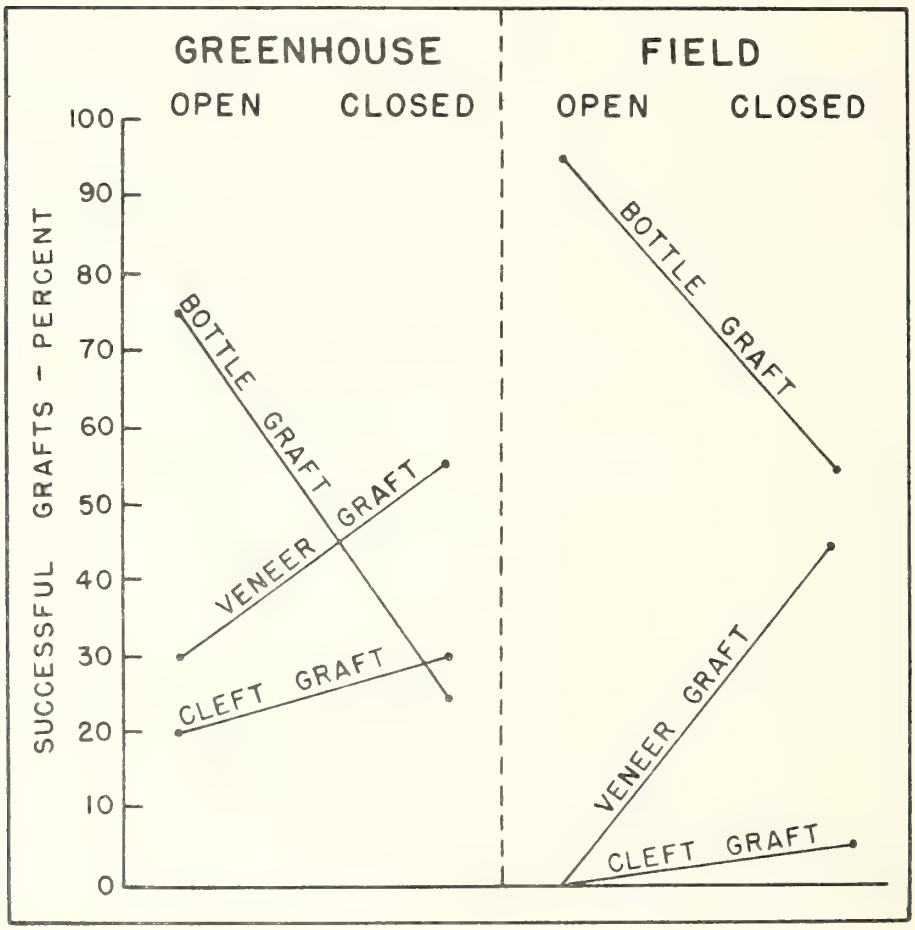

Figure 1.--Relative success of three different grafting methods in four different environments.

Placing both veneer and cleft grafts under sweat-box conditions increased their successful unions, while bottle grafts kept under these conditions had a smaller number of successful unions than those kept in the open. The average temperature in the sweat-boxes in the greenhouse and in the field was always considerably higher than under open conditions. This higher temperature was not depressing enough to completely offset the beneficial effect of the high humidity for the cleft and veneer grafts, but it had a significantly depressing action on the bottle grafts which were not dependent upon high humidities. Under open field conditions where the relative humidity was comparatively low, the only successful unions were obtained with bottle grafts. Veneer and cleft grafts failed completely and most scions had dried out and died after 10 days.

However, when the veneer and cleft grafts were placed in an atmosphere with a high relative humidity, successful grafts were obtained. This would indicate that transpiration was reduced to the point where it did not desiccate the tissue and allowed the scion and stock to form a union.

Pines in general do not develop root pressures under normal conditions, and this fact appears to be one of the main reasons for the low number of successful cleft graft unions in the dormant stage. The only successful cleft grafts were obtained with plants where either a small living limb was below the cut surface or where an epicormic branch was formed on the remaining stub shortly after grafting. Evidently some green foliage is required to act as a pump in supplying water and nutrients from the roots of the stock to the scion.

The bottle-graft method under open field conditions has been successfully used to establish seed orchards for superior forest tree seed.

Grafting during the succulent stage of the growing season presented few problems if the scions were covered by a polyethylene film and kept in full shade during the initial knitting period. A large percentage of successful unions was obtained when stock and scion were in a succulent condition. We found the method suitable for grafting directly on stock growing in the field, and on potted plants in a lath-house or greenhouse. The best time to graft with succulent material is during the later part of April, May, June, or the early part of July. Grafting can be started as soon as the leader has added several inches of new growth, even though not all the needles of the new growth have ruptured the sheath.

As in any type of grafting, the outcome greatly depends upon the condition of the stock. The stock plants should be healthy and in a vigorous growing condition. When potted plants are used, best results will be obtained if they have been in the container for at least six months prior to grafting.

A cleft graft method for succulent grafts is best. After the union is tied and sealed with grafting wax, the graft is covered with a plastic bag. Polyethylene plastic bags of various sizes can be purchased in hardware stores. They are sold as packaging material for deep-freezers. For field grafting the scion is shaded by placing a Kraft paper bag over the plastic bag. Holes should be cut for ventilation in the side of the paper bag which faces north.

Heteroplastic micrografts were made to induce early flowering. One- to four-month-old seedlings were grafted successfully on slash pine, ponderosa pine, pitch pine, eastern white pine, Douglas-fir, white spruce, and Norway spruce. Grafts outside the pine family on Chamaecyparis survived for eight months. No flowers showed after one year. A high anthocyanin content in the needles of heteroplastic grafts was pronounced. Anthocyanin forms in slash pine seedlings during the winter months when they were grown at a low level of nitrogen; also high starch concentrations cause an early and strong anthocyanin formation. The rusty color of some of the scions probably indicated a high C/N ratio in the foliage. If this was the case, the nutritional factors for abundant flowering were favorable, but the factor or factors which tip the balance to transform vegetative growth to flower formation were not present.

Cross sections of graft unions during the formation stages were examined to find out whether past failures in grafting slash pine scions failed because of inherent incompatibilities or because of faulty grafting techniques. The study did not reveal any incompstibilities and showed that parenchymatous cells of medullary rays, phloem, cortex, and cambium, participated in bridging the space between stock and scion tissues. The stock contributed the greatest part of the wound tissue, but the scion took part in callus formation. A continuous bridge between respective anatomical parts of the graft partners was apparent after six weeks.

To sum up the experiments on rooting one can say that advances have been made in this field but a great deal of additional research needs to be done. For grafting, I feel that the methods as tested will be adequate to carry a slash pine tree improvement program through to the grafted seed orchard stage.

(This paper was illustrated by kodachrome slides in addition to Figure 1 above.)

22. REPORT ON THE FOREST GENETICS RESEARCH FOUNDATION[1]

Vertrees Young, Executive Vice-President
Gaylord Container Corporation, Bogalusa, La.

The Forest Genetics Research Foundation is a non-profit corporation established to stimulate the development of forest tree improvement in the United States. It was incorporated in 1951 under the laws of California. Among those active in its formation were the late Dr. Ernest B. Babcock, Professor Emeritus of Genetics at the University of California, James G. Eddy, founder of the Institute of Forest Genetics at Placerville, and Mr. Stephen N. Wyckoff, its present Executive Vice-President. Numbered among its Southern Directors are the following:

Erle Cocke, President
The Fulton National Bank, Atlanta, Georgia

Walter J. Damtoft
The Champion Paper and Fibre Company

E. L. Kurth
Angelina County Lumber Company

J. E. McCaffrey
International Paper Company

Julian F. McGowin
W. T. Smith Lumber Company

G. G. Ware, President
The First National Bank of Leesburg, Leesburg, Florida

P. F. Watzek
Crossett Lumber Company

Vertrees Young
Gaylord Container Corporation

Other directors include men prominent in business, education, and research in the field of forest genetics, among them Scott S. Pauley, our moderator at this morning's meeting.

In the course of an extensive country-wide trip during the early part of this year, which included visits to many of the projects now underway in the field of forest tree improvement, Mr. Wyckoff found that a majority of the technical workers engaged in these projects indicated a need for special studies and research in forest tree physiology, cytology and genetics to provide information required in the

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1/ Presented in lieu of the scheduled report by Stephen N. Wyckoff, who was prevented by illness from attending the Conference.

conduct of these projects. The nature of these studies is such that each could be conducted at one place, at material saving of money and time, with application of results to local conditions to be developed through local, secondary tests. Accordingly, the Foundation proposes to make grants-in-aid to institutes and carry through studies of this kind.

Realizing that the nation-wide development of forest tree improvement is best served by the orderly development of regional programs, the Foundation will make grants-in-aid to regional projects of a technical nature, that are in need of financial aid and that fall clearly within the scope of the regional programs.

It is also recognized that the training of professional men in the skills required to conduct this work requires (1) institutions capable of offering such training, and (2) the reasonable assurance of sustained interest and continuous financial backing for such research, so that men of the proper calibre will feel warranted and reasonably secure in preparing themselves for work in this field.

The Foundation accordingly proposes to assist in this phase of the program, especially with doctoral and post-doctoral fellowships to specially selected individuals for special training in advanced forest genetics and related disciplines.

The ability to carry through the proposed program is of course dependent on the degree of financial support received by the Foundation. A modest start has already been made and some funds have been allocated to various projects. Representations have also been made to "Resources for the Future" for funds to support the work, with the final outcome not yet definitely established.

Speaking as a member of the wood using industries and as such a recipient of numbers of requests for support of this and that project or institution, there would seem to be a rather definite need for an organization which might be the recipient of available funds, with the knowledge of the work that needs to be done, and the agencies capable of doing it, so that the funds in turn might be redistributed so as to avoid unnecessary or undesirable duplication of effort and at the same time, afford support to important phases that might otherwise be overlooked. Few of us in industry are so fully informed as to all that is being done, or that needs to be done, as to be in a position to make the wisest decisions in this new and suddenly very popular field of endeavor.

23. TREE IMPROVEMENT ACTIVITIES AT PLACERVILLE, CALIFORNIA, AFFECTING SOUTHERN SPECIES

F. I. Righter, Forest Geneticist
Institute of Forest Genetics 1/,
California Forest and Range Experiment Station, Placerville, Calif.
Forest Service, U. S. Department of Agriculture

In recent years, the Institute of Forest Genetics has sent out for testing about 85,000 sound seed of southern pine hybrids. They went to four companies, one Chamber of Commerce, five educational institutions, four departments, and five Forest Service experiment stations. Of these agencies 10 are located in your region, five are in the Central States region, two are in the Northeastern region, and one is in Puerto Rico. We will send some seed this month to Iowa where the shortleaf-loblolly F_2 has evidently found favor because of its survival and vigor.

Iowa was not the last place we had in mind when we made the shortleaf-loblolly cross; we didn't even have Iowa in mind at the time! A request by the Forestry School for the seed surprised me, and I shall continue to be surprised, albeit pleasantly, if the hybrids continue to prosper there. We had no particular region in mind when we made the cross. The sole purpose was to test the field performance of shortleaf x loblolly against the performance of shortleaf from the same seed-tree at the Institute. As the hybrids were beginning to suppress the shortleaf trees at 10 years, Jack Duffield removed the latter. Now, we have a very productive seed-orchard of 15-year-old hybrids. We have on hand about 120,000 seed from them.

I mention this example because it illustrates our policy respecting the use of exotics as seed-parents in breeding for the production of F_1 hybrids. Our interest is solely in reconnaisance or exploratory work. We want to find out whether or not two species will cross, what in general may be expected if they do, whether or not the hybrids are fertile, the character of their progenies, and finally the affinity of the hybrids for species other than their parental species. Since your southern species usually do not cross with our western pines, we cannot do anything very practical with the southern pines. They range over so much territory that we would need a good deal more land than we have to accommodate the sizeable samples of all the proveniences of the various species which we would need. In any case in which a species native to the South will cross with a California species, and there is at least one such case, we could, of course, be useful in a practical way.

We usually include pines native to the South in our annual pollination programs. As a result we have obtained, over the years, 9 F_1 hybrids in which at least one of your pines is represented. They are:

1/ Maintained in cooperation with the University of California.

P. caribaea x P. palustris
P. echinata x P. caribaea
P. echinata x P. glabra
P. echinata x P. rigida
P. echinata x P. serotina
P. echinata x P. taeda
P. rigida x P. serotina
P. serotina x P. taeda
P. taeda x P. caribaea

Progenies of hybrids have been produced as follows:

(P. echinata x P. caribaea) x P. caribaea
(P. echinata x P. taeda) F_2
(P. echinata x P. taeda) x P. taeda
(P. echinata x P. taeda) x (P. taeda x P. caribaea)
P. echinata x (P. echinata x P. taeda)
(P. rigida x P. taeda) F_2
P. taeda x (P. echinata x P. taeda)

We are currently testing a form which apparently is the progeny of a longleaf hybrid.

We have a number of hybrids between longleaf and slash pines, produced by Wakeley many years ago.

Our pollination program for 1954 included the following combinations:

P. echinata x P. caribaea
P. echinata x P. rigida
P. echinata x (P. rigida x P. taeda)
(P. rigida x P. taeda) F_2
(P. rigida x P. taeda) x P. echinata
P. taeda x (P. echinata x P. caribaea)
P. virginiana x P. banksiana

This year's nursery will contain materials obtained from crossings involving southern species. The crosses attempted and the number of sound seed obtained follow:

Cross	No. Seed
(P. echinata x P. taeda) x (P. rigida x P. taeda)	953
(P. echinata x P. taeda) x (P. echinata x P. caribaea)	742
(P. rigida x P. taeda) x (P. echinata x P. taeda)	385
(P. rigida x P. taeda) F_2	405
P. taeda x P. clausa	12
P. virginiana x P. clausa	366

No sound seed were obtained from the following attempted hybridizations:

P. pungens x P. clausa
(P. rigida x P. taeda) x P. pungens

Our pollination program for 1955 will probably include some work on southern species.

Possibly we can be of help to you from time to time by making suggestions based on the results of our work with your species.

24. SOUTHERN INSTITUTE OF FOREST GENETICS

Berch W. Henry, Officer in Charge
Southern Institute of Forest Genetics
Southern Forest Experiment Station, Gulfport, Miss.
Forest Service, U. S. Department of Agriculture

The Southern Institute of Forest Genetics, established but a few months ago, is certainly one of the newer members of the group engaged in forest tree improvement research in the South. As a juvenile member, we realize our dependence upon those of you in this group for ideas and guidance, and the need for all of us to work together in this relatively new field of forestry.

It would be presumptuous of me to even consider talking of accomplishments by the Institute per se, during the few months of its existence; they can be summed up by saying: We were established.

I think it might be more appropriate for me to state our objectives as we see them, to outline our current status, and to say a few words about our proposed future program.

We see our general objective as being three-fold in nature and limited at present to the southern pines in substance:

1. To concentrate our efforts upon fundamental genetical and closely related problems, the solution of which would be useful region-wide.

2. To carry out tree improvement studies of an applied nature particularly adapted to our local clime, i.e., southern Mississippi and southeastern Louisiana.

3. To keep ourselves abreast of developments in forest genetics research and application in the South through a repository of published and unpublished information, and through frequent contact with other individuals and agencies involved in this line of endeavor; thus, on a give and take basis, to do our utmost to augment full cooperation in the field of forest tree improvement.

This three-fold general objective, in part or wholly, is possibly quite similar to some of your own. There is nothing particularly new or individualistic about aiming a research program toward fundamental problems, and at the same time having some phases that would be particularly applicable to one's immediate area; in fact it is difficult to devise projects that fall strictly into one category or the other. As to the third phase of our purpose, I believe we all agree that no research project is a well-balanced one if the researchers concerned are not continually cognizant of the progress in their field. In this respect, we shall do our utmost to maintain the standards set by this group in regards to the free interchange of ideas and formation, including but far exceeding that presented in published data.

Now as to our current situation and planned program. The Southern Institute of Forest Genetics replaces the former Gulfcoast Research Center of the Southern Forest Experiment Station, Forest Service, U. S. Department of Agriculture. Our office is in Gulfport, Mississippi, and our field headquarters, including laboratories, greenhouse, nursery, workshops, etc., are on the 4,000-acre Harrison Experimental Forest about 20 miles north of Gulfport.

Our permanent staff consists of four technical men (two foresters, a plant geneticist, and a forest pathologist), three sub-professional technicians, a clerk, and two laborers. We expect to add another forest pathologist next month.

We are financed solely by Congressional appropriations made to the Forest Service, U. S. Department of Agriculture.

Our planned program consists of selected regeneration and tree improvement studies already underway by personnel transferred to the Institute, plus such new studies as can be carried by our current and proposed staff.

The carry-over projects consist of such things as inter- and intra-species hybridization aimed at exploring the compatability of our southern pines; effects of nursery treatment on early height growth of longleaf seedlings; field testing of slash and loblolly pines of known seed source for possible resistance to fusiform rust; field testing of longleaf pine of known seed source for possible resistance to brown spot needle blight; the occurrence of pests in the Southwide Pine Seed Source Study (in cooperation with the Gulfport Forest Insect Laboratory, Southeastern Forest Experiment Station, National Forests, U. S. Department of Agriculture, and State and private agencies); the

control of flower and cone insects (in cooperation with the Gulfport Forest Insect Laboratory); and a southern pine species-site study (in cooperation with industrial, private, and State and National Forest Service agencies).

Our proposed new program will include such studies as the artificial testing of selected slash and loblolly pines for resistance to fusiform rust; the testing of selected longleaf pines for resistance to the brown spot needle blight; the development of desirable pine phenotypes through selection and breeding; the variation between and within species; and the mechanism of inheritance in the southern pines.

25. THE TREE IMPROVEMENT RESEARCH PROGRAM OF THE SOUTHEASTERN FOREST EXPERIMENT STATION

Carl E. Ostrom, Chief
Division of Forest Management Research
Southeastern Forest Experiment Station, Asheville, N. C.
Forest Service, U. S. Department of Agriculture

The Southeastern Forest Experiment Station has major tree improvement projects at its Lake City Research Center in Florida, and its Athens-Macon Research Center in Georgia. The Station also has several individual studies at other locations. The oldest and largest genetics project of the Southeastern Station is the one at Lake City, initiated formally in 1941 under the direction of Harold L. Mitchell. This program was started with only naval stores research money, but was later expanded by Pomeroy to other fields, with the financial assistance of the Florida Board of Forestry. Also cooperating in the Lake City program are the University of Florida, the National Container Corporation, and a number of other pulpwood companies.

The Lake City Program

The Lake City Research Center genetics program includes research in gum-yield inheritance, racial strains of slash pine, superior-tree selection in the nursery and in older stands, techniques of vegetative propagation, and techniques for managing seed-production areas and seed orchards. The most progress to date has been made in the fields of gum-yield inheritance and vegetative propagation. The heritability of gum-yield in longleaf pine has been demonstrated in 17-year-old one-parent progeny resulting from a study started by T. A. Liefeld in 1935. Another major step was verification of the inheritance of gum yield in 9-year-old trees from cross-pollinated and open-pollinated slash pines of high and average gum yield, as described earlier by Pomeroy. A third plantation of several hundred additional seedlings from open-

pollinated and cross-pollinated high-yielding slash pines is not yet old enough for gum-yield determination.

The Lake City center is one of the cooperators in the South-wide Pine Seed-Source Study of the Committee on Southern Forest Tree Improvement. The same center is planting trees this winter for a more intensive local slash pine seed source study involving 16 different geographic origins. A number of other forestry groups are cooperating in this test. The Lake City center is also collaborating with the Athens-Macon Research Center in a local test of loblolly pine seed sources from Georgia and Florida.

A slash pine ecotype study has been started to see if there is any difference in progeny of slash pine from wet and dry sites.

In the field of selection, the major effort in the past was the selection, in the early 1940's, by Dorman, Snow, and others, of a dozen very high-yielding naval stores trees. Nursery selection of superior and odd-type seedlings is now under way on a continuing basis in cooperation with the Florida Forest Service nursery at Olustee. Search has been started also for superior timber-type trees of longleaf and slash pine in existing stands.

Research at Lake City in techniques of vegetative propagation has been stepped up greatly in the past few years to provide the methods needed to perpetuate superior strains. Successful rooting of cuttings from mature trees has now resulted in slash pine saplings that have attained heights up to 25 feet. However, the rooting percentage of severed cuttings from mature trees is still rather low. As described in his talk here earlier, François Mergen had very good success at Lake City in rooting slash pine by the air-layering technique. Mergen also had some outstanding success with grafting in naval stores pines. This work is covered in Station Paper No. 46, "How to Root and Graft Slash Pine," and in other publications.

The Lake City program includes several tests of techniques for managing seed production areas and seed orchards. One test compares four levels of mineral fertilization, two types of stem injury, and one type of root injury with the object of stimulating seed production in six-year-old and 20-year-old plantations of slash pine.

Further details on the genetics program at Lake City are available in Mergen and Pomeroy's Project Analysis, published as Station Paper No. 45.

The Athens-Macon Research Center

The Station's genetics efforts in Georgia started in 1950, when Keith Dorman initiated and gave technical supervision to the genetics program of the Ida Cason Callaway Foundation at Hamilton, Georgia. This program will be described by Aaron Jordan.

In 1954, our Athens-Macon Research Center began a formal forest genetics project at the new Georgia Forestry Center at Macon, with the cooperation and assistance of the Georgia Forest Research Council and the Georgia Forestry Commission. The initial effort in this project is the selection of outstanding individuals of the major southern pines in Georgia, both in natural and planted stands. These selections will be used in one-parent progeny tests, in controlled breeding, and in grafted seed orchards. The staff is also selecting super-seedlings from the four Georgia Forestry Commission nurseries. This will give them the best seedlings out of a total of more than one hundred million grown in the four nurseries each year.

The Athens-Macon Research Center is also initiating a local test of loblolly pine seed sources, mainly in Georgia.

Methods for grafting shortleaf pine have been perfected by Zak at our littleleaf disease project at Athens, in cooperation with the School of Forestry of the University of Georgia. Zak is also engaged in selecting individual trees that appear to be resistant to littleleaf disease, and has been using these in controlled breeding in an attempt to develop resistant strains. A crop of over 1900 seeds from such crosses has already been harvested. One-parent progenies exposed to attack by the littleleaf fungus have shown wide variation in resistance. A study of the relation of littleleaf disease resistance to geographic origin of shortleaf pine has also been started by the Athens office. In this study, stock from seed from a dozen parts of the South has been outplanted on littleleaf sites in the Piedmont of Georgia, South Carolina, and Virginia.

Keith Dorman of the Athens-Macon Research Center also serves as chairman of the technical committee of the Research and Marketing Act project on forest genetics in the Southern agricultural experiment stations. Under this regional RMA project, studies are now active at the Alabama Agricultural Experiment Station in Auburn and the Georgia Agricultural Experiment Station in Athens. Dorman also keeps in close touch with the new project in fundamental genetics at the University of Georgia School of Forestry in cooperation with the Georgia Forest Research Council. Thus, Dorman is in a position to coordinate the Station's genetics work in Georgia with that of other groups in the State.

Other Research Centers

The Southeastern Station's Tidewater Forest Research Center at Franklin, Virginia, has a one-parent progeny test of the inheritance of stem form in loblolly pine. The progeny are now two-years-old. The Santee Research Center in South Carolina is testing eight local seed sources of longleaf pine for planting in the Sandhills, in cooperation with the South Carolina Forestry Commission. The Cordele Research Center in Georgia has a project in the selection of superior strains of slash pine, particularly in its many acres of planted stands on the

George Walton Experimental Forest. These selections are now being utilized in two of the Station's genetics projects.

The Southern Appalachian Research Center at Asheville, North Carolina, has a cooperative test with the Central States Forest Experiment Station of the performance of planted yellow-poplar of 16 different geographic origins. The same research center has a test of six geographic strains of northern red oak, in cooperation with Harvard University, and a 20-year-old test of hybrid poplar clones.

The Division of Forest Insects Research of our Station has been selecting longleaf and slash pines for resistance to black turpentine beetle at Lake City, Florida.

A major accomplishment of the Station was the development of wilt-resistant strains of the mimosa tree by the Division of Forest Disease Research. Two resistant, named varieties have been turned over to the nursery trade. This project has now been transferred to the Agricultural Research Service.

Forest insect and disease specialists at both the Southeastern and Southern Stations have joined hands in a thorough annual check of most of the plantations in the South-wide Pine Seed-Source Study as described earlier in this program by Berch Henry.

26. RESUME OF TREE IMPROVEMENT ACTIVITIES BY THE SOUTHERN FOREST EXPERIMENT STATION

Philip C. Wakeley, Forester
Southern Forest Experiment Station, New Orleans, La.,
Forest Service, U. S. Department of Agriculture

Activities of the Southern Forest Experiment Station have figured directly in six of the reports already presented at this Conference.

The Station is the "chairman organization" of the Subcommittee on Georgraphic Source of Seed, Committee on Southern Forest Tree Improvement, and as such it takes care of the details of coordinating seed collection, stock dispatching, planting, reexaminations, records, and reports, the general principles of which are worked out by the Subcommittee,

Roland Schoenike of the Station staff handles the technical phases of the study of "seed source in reverse" in cooperation with the Crossett Lumber Company, as reported by Sulo Sihvonen.

The Station initiated the original loblolly pine seed source study at Bogalusa, reported by Bercaw, and is continuing it with the cooperation of the Gaylord Container Corporation.

Putnam, near the end of his general paper, described the Station's modest but specific start in phenotypic selection and subsequent progeny testing of cottonwood.

Henry and Coyne have reported the Station's part in investigating diseases and harmful insects in connection with the Southwide Pine Seed Source Study, and Henry has reported on the Station's current and prospective work at the Southern Institute of Forest Genetics.

Six other reports already presented indirectly reflect the Station's work too, either illustrating it or actually arising in part from it.

The Station established and has currently reexamined three of the eight test plantations in the loblolly pine seed source study reported by Wiesehuegel.

Schoenike, at Crossett, has an active program of selection of mature trees like that discussed by Dorman, and one of nursery selection like that discussed by Ellertsen.

Since its first successful controlled crossing of slash pine upon longleaf pine in 1929, the Station has done intermittent work upon hybrids, both artificial and natural, as discussed by Johnson. Several hundred hybrid seedlings from 1951 crosses at Alexandria, Louisiana and the Harrison Experimental Forest in Mississippi were planted in the field in 1953-54, and several hundred bags were pollinated in 1954 at these two centers, at the Crossett Research Center, in Arkansas, and at Many, Louisiana.

In its artificial hybridization, the Station has contributed to techniques, as mentioned by Goddard and Allen.

Part of Maki's data on seed stimulation stemmed from his own work at the Southern Station.

One paper still to come--Campbell's on the program under way at Many, Louisiana--also bears more or less directly on the Station's work in forest tree improvement.

27. THE COOPERATIVE GENETICS PROGRAM AT THE UNIVERSITY OF FLORIDA 1/

Thomas O. Perry
School of Forestry, University of Florida
Gainesville, Fla.

Forest genetics research at the University of Florida has been expanded into a cooperative program between the forest industries of the Southeast and the University. The cooperative program in genetics has three major phases: basic research, education, and direct assistance to industry in application of forest genetics research results. Dr. T. O. Perry and Dr. Chi Wu Wang have charge of the genetics program.

Forest Genetics Education at the University of Florida

Both graduate and undergraduate instruction in forest genetics is offered at the University of Florida. One scholarship for $2,500 is being offered for Ph.D. candidates in the fall of 1955. Eventually, two such scholarships will be offered. A program of forest genetics extension courses is also being offered which will enable practicing foresters to utilize genetics research results in forest management. Ordinarily, it would take about 10 years to train the 25 to 30 Master's degree students needed by Southeastern industries to supervise the applications of new genetics findings. By offering a special six weeks' course to selected foresters from industry we hope to supply this need promptly. We will offer this special course during the winter of 1956. Students taking the course will receive sufficient theoretical and practical training to be able to supervise progeny tests and other experiments involved in developing supplies of superior seed for the industries they represent.

Assistance in Application of Genetics Results

In spite of the newness of genetics on the forestry scene we have available enough research results to show the way to increased profits through controlling the inheritance of our trees as well as their environment. The University of Florida is providing technical assistance and guidance in application of these results. Our plan for establishing seed orchards of selected trees is described in an earlier paper. Field demonstrations of selection procedures, assistance in progeny testing, and a grafting service are all aimed at establishing reliable supplies of high quality seed.

A 4.5 acre nursery is being established to produce about 6,000 grafts a year. Most of the grafted plants will be planted in industry seed orchards.

1/ Read by Dr. C. M. Kaufman, Director, School of Forestry, in the author's absence.

A number of practical research studies are being conducted, of which studies of seed orchard management are an example.

Basic Research Studies in Forest Genetics

The cooperative genetics program at the University of Florida will involve a large amount of practical work and direct technical assistance to the cooperating industries. However, the program has been designed so that much of Dr. Perry's and Dr. Wang's time will be devoted to basic research studies.

A number of projects are now being initiated to determine the genetic variation in response to soil types, rainfall patterns, photoperiod, disease, and other factors of the environment. Ecological and geographic variation in plant species will be the major basic research study conducted at the University of Florida. Most research efforts will be devoted to study of the commercially important conifers of the Southeast. However, a significant amount of energy will be devoted to studying cypress and hardwood species.

The genetics of the grass stage in longleaf pine, drought resistance, and adaptability of sand pine to oak ridge sites will be under consideration in the next two years. Experiments on the genetics of fall color change in red gum will serve to reveal why some trees turn red and some remain green with the onset of cold weather.

28. PROGRAM OF TREE IMPROVEMENT RESEARCH, TEXAS FOREST SERVICE

Bruce Zobel, Silviculturist
Texas Forest Service, College Station, Texas

Active forest tree improvement research by the Texas Forest Service began in 1951. The research program is financed through three sources: (1) forest products industries and landowners interested in forestry, who provide funds for some operating expenses and for graduate-student fellowships; (2) the Texas Forest Service, which pays salaries of research personnel and provides funds for some equipment and field operations; and (3) the Agricultural and Mechanical College of Texas, which makes available a laboratory, greenhouse, and office facilities.

We have at present two graduate students, both in attendance at this meeting, who are well advanced toward the PhD degree. In 1955 we will have the funds and facilities to grant three new fellowships towards the PhD. To be eligible for these fellowships, each $2,080 per year for out-of-state students, the student should already have a

Master's degree in forestry or related biological science. The graduate student's research problem is chosen by the student from the numerous basic problems confronting us in our tree improvement research. We will supply anyone interested with the details of the fellowship. I want to point out that these are fellowships, not assistantships. The fellow spends full time on academic work and research.

We have made a very strong effort to have a well balanced tree improvement research program. An attempt has been made to have a balance between long-term and short-term projects, and between basic and applied research. There often is the temptation to emphasize the short-term projects. Such projects yield numerous quick publications and are perhaps suited to organizations whose continuity is not assured. But the productive projects in tree improvement are usually long-time studies. In working with these long-term studies, a number of important short-term problems are encountered which must be attacked.

At the present time the Texas Forest Service has 10 active projects underway. I will mention a few of them to illustrate what is being done.

Despite a lot of interest, there has been practically no work in the genetics of wood characters. Long-term studies in this field are very important in forest genetics. Therefore, in 1951, the Texas Forest Service started a project on the genetics of wood specific gravity. This study is now well underway. As work progressed in this project, other fields of interest came to view and now many projects in this general field are possible. For example, a parallel to inheritance of specific gravity is a study of inheritance of fiber characteristics. Immediately we were faced with the fact that practically nothing is known of the physiology of wood production, i.e., such questions as, "why does a tree stop producing springwood and start producing summerwood?" Mr. VanBuijtenen, one of our graduate students, is now working on some of the basic phases of growth physiology that may supply the answer. Many more need to be undertaken. For example, in our study of genetics of the inheritance of wood specific gravity many statements were encountered in the literature which, on observation, did not seem to hold for loblolly pine in the Western Gulf Region. Therefore, a project on environmental control of wood specific gravity was initiated. Results of this investigation will be published soon.

I reported yesterday on the drought-resistance studies being undertaken by the Texas Forest Service. We also have underway studies on the selection and value of so called superior trees, and of outstanding nursery seedlings.

One graduate student is working on the very difficult problem of the vegetative propagation of older loblolly pines.

We have established a breeding arboretum of pine exotics and of available pine hybrids that will grow in Texas. As most of you are doing, we are cooperating on the southwide study of geographic races. In addition we have studies underway on pollen collection and handling, care and treatment of seed orchards and seed production areas, and studies and observations on flowering and root development.

Some of our problems are regional, some strictly local. In either case, we have cooperated freely with other organizations doing similar research. We attempt to answer all questions to the best of our knowledge, and aid any other research within our limitations.

For anyone interested in more details of the Texas Forest Service Tree Improvement Program, we will gladly send you a copy of our "Second Progress Report". This is prepared yearly for our sponsors. Projects underway are discussed, publications are described, and other information about our tree improvement program is outlined.

29. PROGRESS REPORT FROM IDA CASON CALLAWAY FOUNDATION

Aaron Jordan
Ida Cason Callaway Foundation, Hamilton, Ga.

The program of the Ida Cason Callaway Foundation at Hamilton, Georgia for the development of superior southern pines, is now in its fifth year. During the first four years a wide selection of plus trees was made, and the progeny of some of these mother trees have had several years of field testing. A small number of inter-species and intra-species crosses have been made and the progeny of these crosses have been outplanted under field conditions as the seedlings resulting from these crosses have become available.

Beginning with this fifth year, we feel that results so far have been sufficiently indicative to warrant more concentrated attention to a selected group of the plus trees, and to the initiation of seed orchards. The Foundation project has been carried on with studies of the four southern pines found in its locality--loblolly, slash, shortleaf, and longleaf pine. Out of the hundreds of plus trees selected among these four species, a few of each will be the basis of future activities. We expect to work with these species in the percentage ratios of 40 for loblolly pine; 40 for slash pine; and 10 each for shortleaf and longleaf pines. The number of plus trees on which this work will be concentrated is about six or eight of each species.

The selection of these plus trees will be the ones forming our seed orchards which have been based on performance of the progeny in

the seed beds and in the outplantings. Growth measurements have been carefully kept. As might be expected, these figures have shown that some plus trees have produced progeny which, after an initial superiority in the seed beds and outplantings, have not kept up their advantage over the full period. The progeny of other plus trees have also developed superiority that did not show up in the first year or two.

Seed was collected this past fall from only those trees which showed the best promise so far. Cone count and seed quantity was kept for each mother tree. These seeds will form our nursery production for 1955.

We will have some surplus seedlings from last year's nursery production. The seedlings from the select group of plus trees will be planted this winter to start the seed orchards with open-pollinated seedlings. Next year's production, and that for a few following years, will be used to extend the acreage of seed orchards. The proper combinations of progeny will be worked out so that natural cross-pollination within the seed orchards will produce the superior type of seedlings for commercial use for which we have been striving. We expect that eventually we will have certified seed, as well as seedlings, to offer the tree-planting public.

Concurrently with this program will be the continuation of testing progeny in the outplantings, and the keeping of records as to their growth, health, form, and other characteristics.

Vegetative propogation will also be on the program. Working in cooperation with other agencies engaged in this problem we will be active in trying to work out techniques of grafting, rooting, and air-layering, but we do not expect to make this a major part of our program.

We believe that we have reached a corner in our project, and that by turning this corner in the direction of practical application of what we have learned so far, we will bring closer the realization of our goal. The goal, of course, is to improve the economic situation of the South, with our contribution being the supplying of superior pines to build up the forest lands of the South.

30. TREE IMPROVEMENT PROGRAM OF A. J. HODGES INDUSTRIES, INC.

Thomas E. Campbell
A. J. Hodges Industries, Inc., Many, La.

The Experimental Area of A. J. Hodges Industries, Inc. was established for the development of better pine trees for southern pine consumers, and for the experimental study of fish and game.

The area is located on U. S. Highway 171 between Hornbeck and Florien, Sabine Parish, Louisiana. It consists of 4,500 acres enclosed in an eight foot woven wire fence. The northern edge of the longleaf pine belt runs through this area.

One phase of our work includes fish and game management in cooperation with Louisiana State University, School of Forestry, Department of Fish and Game Research, directed by Dr. Bryant A. Bateman.

One 225 acre man-made lake has been stocked with large-mouth black bass and bluegill bream. Four small ponds of one to five acres in size are being used for research for various other species of fish.

Deer, elk, and turkeys have been stocked for propogation. The deer herd is comprised of the native white-tail, mule deer, Japanese fan tail sika, and three varieties of the European fallow deer. One of these is solid white, one chocolate brown, and one white and chestnut spotted, resembling the white-tail fawn. These deer, one bull elk and three cow elk were all imported from a game farm in Wisconsin. Pen-reared turkeys were imported from northeast Louisiana for stocking purposes.

Our major interest, of course, lies in forest research. We are following what might be called a five-point program. Though not listed according to priority, these are our problems:

1. Working with other interested parties on shortening the "grass stage" of longleaf pine.

2. Producing dense-wood trees for the pulpwood industry--selecting trees having dense wood (a large percentage of summer wood as compared to wood produced by spring growth) and propagating them through subsequent generations.

3. Seeking a "superior tree" that will combine rapid growth, high quality lumber, disease resistance, and drought hardiness. This problem is attacked by crossing species and individual trees, each having one or more of the desirable characteristics, then field testing the progeny resulting from such hybridization.

4. Establishing an arboretum. We are in the process of collecting all of the some ninety-one species of pine in the world that will grow in northwest Louisiana. These are planted in a concentrated area for observation of growth and quality characteristics and for hybridization purposes. At present, we have obtained forty-six species.

5. Vegetative propagation. Getting root formation on pine trees of merchantable size classes has long been known as a definite need, yet in some cases, pine is rather stubborn about producing roots. A large number of people have attacked this problem from a great many angles with little success, particularly with loblolly pine.

We are working on the idea of rooting cuttings in greenhouse beds. As far as is known by the writer, no success has ever been attained in rooting loblolly pine cuttings.

We have for this purpose a specially constructed greenhouse in which the air temperature, relative humidity and soil temperature can be rigidly controlled. These are kept at 62-65 degrees F., 85-95 percent and 80 degrees F. respectively. These conditions are maintained constantly. Under these ideal atmospheric and soil conditions, we use six different types of rooting mediums combined with various chemical and rooting hormone treatments, giving us twenty-one different combinations of treatment.

To date, after twelve weeks in the greenhouse beds, some degree of success has been noted on cuttings from one-and three-year-old seedlings. Although no rooting has been seen on any of the cuttings from mature trees, we are very encouraged about the fact that we have rooted loblolly pine. Perhaps the mature cuttings will require a more refined version of the method we are now using. This will be our next problem.

In our Forest Research program, we are pooling our efforts in cooperation with the following:

The Texas Forest Service
Forest Genetics Laboratory
Texas A & M College
Dr. Bruce Zobel

Forest Service, U. S. Department of Agriculture
Southern Forest Experiment Station
Philip C. Wakeley

Louisiana State University
School of Forestry
Professor A. B. Crow

We also exchange information and ideas with any other person, organization, or institution which has a mutual interest in the Southern Pine Tree Improvement Program.

31. TREE IMPROVEMENT ACTIVITIES AT THE ALABAMA POLYTECHNIC INSTITUTE

George I. Garin, Forester
Alabama Polytechnic Institute, Auburn, Ala.

In reviewing forest tree improvement work at Auburn, it will be necessary to mention briefly two old projects. You probably know that

the Alabama Polytechnic Institute pioneered in planting slash pine north of its natural range. As early as 1927, experimental slash pine plantations were established at Auburn, a location about 100 miles north of the natural range of this important tree species. Since 1927, and in no small measure due to the success of these early plantations, slash pine has been extensively planted in many parts of the South north of its natural range.

Another project was started in 1940. Arizona cypress was successfully introduced to Alabama and, later, to other areas in the South. This is a tree well adapted for Christmas tree production. Experimental work with Arizona cypress is continuing at Auburn. It is directed mainly toward developing better and more economical methods of producing high quality Christmas trees. For a number of years grafting and rooting of Arizona cypress cuttings have been tried at Auburn. Like many other conifers, Arizona cypress is difficult to graft or root, but a certain amount of success has been achieved. Arizona cypress apparently is one of the most genetically variable trees. Trees of excellent quality have been produced from outstanding parent material. Only the trees of best form, of course, are useful in Christmas tree production. A typical Arizona cypress plantation provides a good example of wide variability in trees. The differences between individual trees probably are due to inheritance.

Several crosses of loblolly and shortleaf pines, furnished by the Institute of Forest Genetics in California, are being tested at Auburn. These crosses were planted, according to a specific experimental design, in competition and comparison with pure loblolly and shortleaf pines.

Auburn is participating in the southwide study of geographic seed sources that is directed and coordinated by a subcommittee of the Southern Forest Tree Improvement Committee. Six lots of shortleaf pine and nine lots of loblolly pine have been planted on an outlying experimental forest in Coosa county. Good survival was obtained and the plantations can be included among those established elsewhere, and classed as the successful.

In addition to the standard seed source plantations, stock of known geographic origin was used to replicate the experiment in part on another experimental forest in Autauga county. The seedlings came from surplus stock raised in the Auburn Nursery. Shortleaf, loblolly, and longleaf pine were planted.

Our most important undertaking in forest tree improvement work is just being started. It is basic research in physiology of small seedlings. Early in 1954 the Association of Southern Directors of the Agricultural Experiment Stations approved a regional project in forest tree improvement. The title of the project is "The application of genetics and cytology to the improvement of southern pines". Under

the general scope and objectives of this project, a contributing state project was initiated by the Alabama Agricultural Experiment Station under the title: "Some physiological characteristics of the progeny of selected southern pines and their interrelation with nursery practices, survival, and early growth". The project was approved by all committees concerned and by the Office of Experiment Stations in Washington on November 15, 1954.

This project is broad in scope. It was necessary to divide the work into several phases. The work now under way is concerned with "The food reserves of genetically selected southern pine seedlings". A. R. Gilmore and J. T. May are co-project leaders. Because the work is so new, there are no accomplishments to report. Next year, a report can be made on progress of this work and, perhaps, on other phases of the project.

The Auburn study is a cooperative one and supports regional work in tree improvement sponsored by the state agricultural experiment station. It is designed to go one step further in the genetics program. It proposes to evaluate the effects, if any, of nursery management on inherited superior characteristics and to compare superior stock with average stock. The work at Auburn is dependent on obtaining materials from geneticists working at other centers. Such cooperation is already being received from Georgia and additional materials may be supplied by the Texas Station. In our search for small supplies of genetically distinct strains of pines, we undoubtedly will be making contacts with other agencies. Cooperation is one of the cornerstones of tree improvement work in the South, and, fortunately, everybody is imbued with a spirit of generosity and is sharing what he has.

You can see that work in forest tree improvement at Auburn is slanted toward physiology and is related to research in nursery management. Further work is planned to test stock of superior pines on various planting sites. Hence, the third segment of the tree improvement program will be covered and problems of landowners wishing to plant this stock will be evaluated and, it is hoped, solved.

In Alabama we have not received large grants for research work in forest genetics. Money made available for this work has been channelled into basic research as previously outlined. We feel that selection of superior trees and establishment of seed orchards and seed producing areas is being adequately studied elsewhere at present. This type of work is highly important to the planting programs of the immediate future. We think, nevertheless, that our work will make its contribution to the overall tree improvement program in the South and will add to work already under way.

32. THE TREE IMPROVEMENT PROGRAM OF THE MISSISSIPPI FORESTRY COMMISSION

Hoy C. Grigsby
Mississippi Forestry Commission, Jackson, Mississippi

In 1952 the attention of the Mississippi Forestry Commission was focused on the widespread deterioration of the forest stands of the state through dysgenic cutting practices. Encouraged by an occasional report on work underway in forest genetics, the Commission made a decision to check into the possibility of selecting and propagating superior trees. In June of that year, one forester was placed on full-time tree improvement work. After further study, the Commission decided to set up a program of tree improvement with the greatest emphasis for the present on selection. The Commission feels that, in the beginning, greater results can be achieved in a shorter time through selection. We will have come a long way when we seek out and propagate the best trees that are now growing in our forests. And, too, tree improvement by selection is not limited to the geneticist. It can be practiced now by foresters, timbermen, and even farmers, for it is basically a refinement of the selection system of management.

While we are not unaware of the possibility of greater gains eventually coming from hybridization, there's no getting around it, hybridization takes time. I know of a geneticist working with cotton here in the South who grows a hybrid crop during the regular season, harvests the cross-pollinated seeds, and sends them to a cooperating experiment station in Mexico where another crop is grown through the winter. Forest trees, unfortunately, require more time than cotton to hybridize. Under certain conditions some trees will bear seed in four to six years, but a tree must grow to maturity--or at least to merchantable size--before we can be absolutely sure of its characteristics. Hybridization is pretty exacting work and only a small number of our foresters have sufficient training to carry out a hybridization program.

Although most of our (the Mississippi Forestry Commission's) work is directed towards selection for the present, we are not forsaking hybridization. We are hybridizing some of our most outstanding selections.

One of the first steps undertaken in our program was to educate and sell our field personnel on the value and need of forest tree improvement. This was done through the use of charts, exhibits, slides, pamphlets and field work with them at forest management schools.

Then we enlisted the cooperation of the federal, industry, and private foresters, and also the naval stores operations of the state. This group of 326 foresters and naval stores operators have been very

cooperative in reporting outstanding trees. The rate at which these reports are being received is more than gratifying. To date, 72 reports have come in and from this number we have chosen five trees for propagation and testing. A total of 24 pine and hardwood trees have been selected. As better trees are found, some of these will be discarded. All of these trees are catalogued and duplicate records can be sent to the Committee on Southern Forest Tree Improvement when and if the Committee sees fit to set up a central catalogue.

Three of the high gum yielding pines reported by naval stores operators are under test and last year two of them produced more than twice as much gum as the check trees. No attempt will be made to go into naval stores tree improvement with the thoroughness that is being done by the Lake City Research Center of the Southeastern Forest Experiment Station, of course. But since Southeast Mississippi is an active naval stores area, we feel that we are justified in checking and propagating the most outstanding trees reported to us.

Three methods of propagation are being used. First open-pollinated seeds are collected from a tree. Then the tree is reproduced vegetatively by grafts. Later, progeny from controlled breeding are obtained. We do not yet have any outplantings from our controlled pollination work.

The Forestry Commission has been fortunate in getting the assistance and facilities of the Department of Horticulture at Mississippi State College in its vegetative propagation work. A horticulturist specializing in the vegetative propagation of ornamental plants is working closely with us. We have had reasonably good success with grafting, but none at all with rooting.

A new type of grafting, a variation of the bare-root method used with ornamentals, showed considerable promise last year and will be tried again this spring. Seedlings used for grafting stock are placed in sand (heeled in) in a greenhouse and the humidity is kept high. A side graft is made after root action begins. When union takes place, the stock plant is pruned back in the conventional manner. It is then potted and moved to a lathhouse. The advantage in using this method of grafting is that it saves the costly greenhouse space that is consumed by pots. About 30 grafts per square foot can be made when this method is used.

Three test areas, two in Southwest and one in Southeast Mississippi, have been set up for testing selected tree progeny.

Our first controlled pollination work was done in loblolly pine in the spring of 1953. Heavy cloth bags were used. Conelet mortality was high and the few that survived pollination were lost to cone insects or to squirrels. Our efforts last year were more fruitful. Sausage casing bags were used on slash, loblolly, and longleaf pines with only two percent flower mortality. No insect damage has been noted.

Outstanding pine seedlings have been selected from the nursery beds for the past three years and, together with check seedlings, have been planted in test areas in an effort to isolate individuals with superior vigor. For the past two years, the seed has been graded into four size classes to make these selections more accurate.

In addition to selecting superior seedlings from the nurseries, all discernable natural hybrids and odd or freak seedlings are being removed and planted separately. These seedlings will be kept under observation and some of them will no doubt be utilized when we work further into a program of hybridization. I doubt if we who are in tree improvement work utilize this means of selecting natural hybrids as fully as we should. Differences between individuals readily show up in nursery beds and no where else can we view so many trees so easily.

Last year, in cooperation with the Crossett Research Center of the Southern Forest Experiment Station, a seed source study was put in involving Crossett, Arkansas, seed and seed from Northeast and Southwest Mississippi. The purpose of this study is to determine if Mississippi and Southeast Arkansas can safely exchange seed or seedlings in case of crop failures in either place. Two plantations were put in, one in Northeast and one in Southwest Mississippi, with each of the three sources being replicated five times.

Inasmuch as loblolly pine has a range of more than 300 miles north to south within the state, and as it is the most sought-after species for planting, a local seed source study will be put in next year to determine how far in latitude seedlings can be moved from points of origin without harmful effects. Seed were collected for this project last fall.

33. TREE IMPROVEMENT ACTIVITIES AT NORTH CAROLINA STATE COLLEGE

T. E. Maki, Professor of Forest Management
School of Forestry, North Carolina State College
Raleigh, N. C.

As yet there is no formal program in Forest Genetics at the School of Forestry, North Carolina State College. However, some existing studies and future investigative work are designed to contribute to tree improvement, at least in a small way. Additional research on a more substantial basis is planned for initiation as soon as funds and manpower permit.

Included in the present studies are:

1. A small test of certain selections of loblolly and shortleaf pines from the Southwide Pine Seed Source Study. The stock for this test was grown in the Clayton Nursery in Johnston County, North Carolina, and out-planted on two School Forests,--the Hope Valley Forest in Chatham County and the Hill Demonstration Forest in Durham County. The test is not designed for rigorous assessment of source differences, but should provide bonafide specimens for future breeding and other tree improvement activities.

2. A small test, in cooperation with the Institute of Forest Genetics, Placerville, California, involving mainly hybrids of shortleaf and loblolly pines. Outplantings of this stock on the Hill Forest in Durham County and near the Clayton Nursery in Johnston County are re-examined periodically. Records include height growth, vigor, incidence of tip moth infestation, etc.

3. A test of local seed source of loblolly pine, involving a 10-tree sample of seed from each of three school Forests: the Richland Creek Forest in Wake County, the Hope Valley Forest, and the Hill Demonstration Forest. These forests are located roughly at the apices of an isosceles triangle, with the base equal to 40 miles, and the two sides about 30 miles each. The test is in its first year in the field, and no startling differences have become manifest as yet. Seed from all 30 trees were tested in the greenhouse and showed the usual large between tree differences, which were not too clearly associated with source. Of some interest was the observation that one tree consistently suffered heavy damping-off losses in all five replication, heavy losses occurring even when the two adjacent rows (with rows spaced two inches apart) were completely free of loss.

4. A test of longleaf pine from the deep sand area of Bladen County, North Carolina, and from the sandhills region of Chesterfield County in northern South Carolina and from Aiken County on the Georgia border. This project is in cooperation with the North Carolina State Forest Service, the Southeastern Forest Experiment Station, the South Carolina Forestry Commission, and the Atomic Energy Commission. The seed source or genetic phase of this study is only incidental to the main objective of determining whether certain nursery treatments, coupled with planting site preparation, will improve survival of longleaf pine and stimulate early height growth. It will, however, provide documented plots of known seed source for possible use in future tree improvement work.

Work planned for initiation in the near future includes:

1. A test of white pine seed source to determine whether a "boreal remnant" of about 200 acres in extent of white pine at the confluence of Deep River and Rocky River in Chatham County represents a different strain from that of the main white pine type about 150 miles westward in the Appalachian foothills. A population sample of cuttings, or rather twigs to be used in cuttage and graftage, was sent to Dr. Heimburger in Maple, Ontario, nearly 2 years ago to be used in his studies of disease resistance.

2. A test of gamma ray, X-ray, and neutron radiation of pine and hardwood seed to determine whether mutations might be induced.

3. A start toward evaluation and measurement of the range of genetic variability in species and races of some commercial hardwoods, the initial work to begin on yellow-poplar and redgum.

In the field of forest genetics education, we offer no genetics course, as such, in the School of Forestry. However, advanced undergraduates are encouraged to select the general genetics course offered by the Genetics Department as an elective. Several of the Master's candidates select one or more genetics courses in their graduate program, and some choose genetics as a minor field. North Carolina State College is prepared to offer both the Master's and the Doctoral degree in forest genetics; she has a Genetics Faculty of 28 distinguished scientists at present, this faculty cutting across departmental lines. In addition, the Institute of Statistics greatly strengthens the whole program of teaching and research in the field of genetics.

34. FOREST GENETICS RESEARCH AT THE UNIVERSITY OF GEORGIA

Mervin Reines
School of Forestry, University of Georgia, Athens, Ga.

The School of Forestry at the University of Georgia has recently become part of a quadripartite cooperative agreement between the Georgia Forest Research Council, the School of Forestry, the Georgia Forestry Commission, and the Southeastern Forest Experiment Station of the Forest Service, U. S. Department of Agriculture. The agreement is aimed at developing and expanding an adequate forest research program in the state of Georgia. Under this arrangement a genetics program has been initiated.

Total contributions to the genetics program amount to $22,350, of which $8,850 was given by the School, $11,100 by the Georgia Forest Research Council, and $2,400 by the Georgia Forestry Commission.

The work at the School of Forestry has been, is being, and will be coordinated with that of other agencies through the efforts of Mr. Keith Dorman of the Southeastern Forest Experiment Station.

Fully realizing that individual tree selection and seed certification are the most practical and immediate measures necessary in a tree improvement program, our first and introductory project involves tree selection, the collection of seed resulting from open and controlled pollination and of clonal material from selected parent trees,

and the establishment of an arboretum or outplanting area. Such an area will be used for the planting of seed and propagated clonal material from selected trees for future breeding and hybridization, genetic studies, progeny tests, and seed sources.

Trees are being selected from various sites in different locations and for specific characteristics. At present our selections are being limited to the four major pines in the region. Future study may involve other species, both gymnospermous and angiospermous. Selections are to be made on the bases of: clear length of stem and tree height, taper of stem, straightness of grain of wood, diameter of branches, angle of branches, diameter of the bole, forking of the stem, straightness of stem, natural pruning ability, apical dominance, narrowness of crown, seed production, flare of butt, sprouting of epicormic buds, wood density, cell size, cell wall thickness and the relative amounts of earlywood and latewood, fiber length, disease resistance and other characters as yet unclassified. At present selections are being made on the bases of form and vigor. Within these selected trees other qualitative factors will be considered.

A second project has been initiated to consider vegetative propagation; its morphology, physiology, techniques, and practical application. The objectives of this project are: (1) to seek better techniques; (2) to ascertain the effects of age, type, condition, and source position on vegetative propagation; (3) to investigate the effects of environmental conditions and seasonal relationships on vegetative propagation; (4) to study the morphological and physiological aspects of the union of stock and scion in grafting, callous formation, and root development on cuttings.

A third project, now in the thinking mill, will involve the study of the nature of flowering and cone production from the morphological, physiological, and genetical standpoints, with the view towards finding methods whereby anthesis may be stimulated in younger trees.

Future studies will be made of the mode of inheritance of specific characters supplemented by anatomical and cytogenetical considerations, and of vegetative vigor as it may possibly be correlated with chromosome number. Breeding and hybridization will be undertaken.

Mr. Boyd M. Witherow is sharing in these labors.

Also under the Research and Marketing Act financial support has been provided for a genetics program now under the leadership of Dr. L. W. R. Jackson. He is assisted by Mr. James Greene formerly of the Ida Cason Callaway Foundation Tree improvement program, now a graduate student in the School of Forestry at the University of Georgia.

Their efforts are now directed toward a comparative study of certain anatomical features of slash pine parents and the progeny

produced by controlled pollination and open pollination. Such anatomical features as resin ducts, tracheid length, and earlywood and latewood are under consideration. Specific gravity is foremost among the physical properties of wood being examined.

35. TREE IMPROVEMENT ACTIVITIES OF FOREST FARMERS ASSOCIATION COOPERATIVE

J. Walter Myers, Jr., Executive Director
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(Mr. Myers reported informally on the plans of the Association for further support of forest genetics research and other forest research. As these plans were still tentative and incomplete, however, he submitted no paper for inclusion in these proceedings.)

36. RESUMÉ OF THE THIRD SOUTHERN FOREST TREE IMPROVEMENT CONFERENCE

Scott S. Pauley
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Although a Yankee type with strictly Mendelian segregationist sympathies, I have had the privilege and good fortune to have attended all of the Southwide forest tree improvement conferences sponsored by the Committee on Southern Forest Tree Improvement. As an outsider looking on, I can with complete objectivity and frankness tell you, first of all, that the one thing that has most impressed me at this meeting (aside, of course, from the bells) is the abundant evidence that you all seem to have been pretty serious in Atlanta, back in January 1951.

In the heat of enthusiasm, there is nothing easier than to make extravagant and far-reaching plans. I must confess that at the first meeting in Atlanta, and for some time thereafter, I was frankly worried. Subsequently, however, my worries and doubts faded away. I must say that the Committee on Southern Forest Tree Improvement and its cooperating individuals and agencies is the "followingest-through" group I have ever seen in operation.

I was expecially interested in yesterday's first session concerned with the problems of seed source, the groundwork for which was so ably laid by Rudolf. The "Southwide Cooperative Study of Geographic Sources of Southern Pine Seed", a current evaluation of which was presented by Wakeley, Henry, and Coyne, is probably one of the best examples of "follow-through" that has been demonstrated by the Committee on Southern Forest Tree Improvement. In view of the numerous individuals and agencies that have so freely worked on the venture, it stands as a model of cooperative effort that might well be copied in other regions.

Wiesehuegel's report on results of the Tennessee Valley Authority's racial studies of loblolly pine, Sihvonen's account of Crossett's "Corrigan Study" of seed source in reverse, and Bercaw's up-to-date report on the old loblolly seed source study at Bogalusa provided added evidence that interest in seed source--the logical point of departure in tree improvement efforts--is still a lively topic of interest in Southern silviculture.

I have often expressed the opinion that such fundamental, extensive studies as those concerned with the study of wild tree variability at the racial, stand, or individual tree level, is not only scientific good sense, but practical good sense as well. From the practical standpoint the initial pursuit of such studies will provide quickly what the South needs badly, namely, good wild native seed in commercial quantities. Scientifically, the knowledge accumulated on the variation pattern at the racial level is essential to adequate analysis on the stand or individual tree level. As such knowledge accumulates, its further practical applications will be manifold in the more intensive phases of tree improvement in the future.

While on this subject, I would like to make one brief comment on a fact that tree-improvers, and especially the emissaries of intensive breeding, frequently overlook. It is simply this: we are inclined to minimize the very important fact that through the Grace of God and a highly favorable series of evolutionary processes, the South already has some mighty good trees. If your slash pine, for example, did not exist, I would accept with reluctance the responsibility of breeding (even with all the top quality raw genetic material in the whole of the genus Pinus at my disposal) a mythical "slash pine" endowed with the numerous superior characteristics possessed by Pinus elliottii--variety elliottii, that is.

For this reason I was particularly pleased to hear Dorman emphasize the importance of individual tree selection, and was reassured to learn of the attention being given to this phase of Southern tree improvement as reported in yesterday afternoon's session by Ellertson, Zobel, and Pomeroy.

Putnam's paper on the need for genetic research in southern hardwoods was not only of special interest to me because of my own

interest in hardwood genera, but is a valuable and timely reminder to you piney woods runners that the South's claim to fame rests not alone on cotton, corn, and pine.

You in attendance at this Third Southern Conference on Forest Tree Improvement have been especially fortunate in having with you two of the best informed men in this country, if not the world, on the genus Pinus. I refer, of course, to Pete Righter and Al Johnson. There can be no doubt but that the pioneering work in inter-specific hybridization which has been done at the Institute of Forest Genetics in Placerville will have far-reaching and beneficial influences on pine improvement work throughout the South. Although Al Johnson's remarks here have been confined to a discussion of natural and artificial hybridization in the southern pines, I can assure you that he could speak as authoritatively about the pines of Mexico or China.

To those of you unfamiliar with the pollination and hybridization techniques developed or improved here in the South, Goddard and Allen's paper was valuable and instructive.

Chi Wu Wang's off-the-cuff report on the cooperative seed orchard program, underway in Florida under sponsorship of the University of Florida and various wood-using industries, was another reminder that the Committee on Southern Forest Tree Improvement apparently has few desk-chair operators. This fact was further confirmed by the enforced absence of Tom Perry who was originally scheduled to appear. I think that one of my cherished memories of this conference will be Chi Wu's definition of a phenotypically élite tree.

Maki's summary of work done on the stimulation of seed production was most timely, in view of current plans for seed orchard establishment in Florida and other parts of the South. Crossett and Westvaco, already in the seed production business, could, I think, profitably undertake research in this area. One of the prime weaknesses of most of the previous physiological studies concerned with the stimulation of flower and fruit production in forest trees has apparently been a failure to recognize that fruitfulness may well be under rigid genetic control in some tree populations. There is at least considerable empirical evidence to indicate that local populations may be highly variable with respect to individual tree fruitfulness. For this reason a well planned study of the effects of strangulation, fertilization, and other treatments on fruitfulness undertaken on a series of clonal lines, rather than a group of wild trees of mixed heredity, might well prove highly informative.

I was much interested in Easley's report, read in absentia by Gustafson, on Westvaco's seed-producing areas. It is my confirmed opinion that the seed-producing area system as developed by Westvaco is one of the cleverest examples of Yankee ingenuity I have encountered in the South.

The final item on the agenda yesterday, the film "Developing Pedigreed Trees", produced by the Mississippi Forestry Commission's team of Grigsby, and Shotts, is, without exception, the finest piece of forest tree improvement propaganda I have seen. I hope it will have wide distribution.

Zak's paper on grafting techniques and Mergen's on the rooting and grafting of slash pine provide abundant evidence that this important area of research is not being neglected in the South. The results obtained by air-layering and the development of grafting methods suitable to the southern pines are of great potential value, chiefly as they relate to the pursuit of knowledge in other phases of the tree improvement research effort.

The brief reports that have just been concluded by representatives of various research agencies and foundations actively engaged in, or sponsoring research in, southern forest tree improvement, leaves one with the distinct impression that a Fourth Southern Conference is definitely on the way.

There are, in closing, a few general remarks I would like to make directed to those of you present at this conference who may not be directly engaged in tree improvement work. On the basis of the reports given, you might conclude that there is an inordinate amount of overlap and duplication of research effort by the various agencies concerned. This is, in a general sense, true. But it is by no means bad. It is, in fact, necessary and healthful. It is necessary, first of all, because the South is simply a big area, and I might say that this is true even if Texas is excluded. In consequence, though basic procedures are the same, the selection and isolation of élite wild loblolly pine in North Carolina, for example, is genetically and environmentally a wholly different problem from the identical job undertaken in east Texas.

In this connection I read recently--just where I can't remember--that all the recent work concerned with the establishment of seed source studies was a ridiculous waste of time and money. Why? Because, the author pointed out, it has long ago been well established that racial diversity in trees <u>does</u> exist!

I mentioned also that duplication and overlap of effort was healthful. And this is true even in the same region, preferably right next door, because, scientifically, there is nothing more healthful than having someone else test someone's hypotheses.

Finally, in addition to the vote of thanks that this body has already formally extended to the local arrangements and program committees, I wish to add my own small paean for a job exceedingly well done. This meeting has, in my estimation, been a success not only in the professional sense, but it has proved to be one of the most wakeful affairs of this kind I have ever attended. So to the bell-ringer of Newcomb College I think we owe a special vote of thanks.

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Previous publications and reports prepared in cooperation with the Committee on Southern Forest Tree Improvement are:

1. Report of the first southern conference on forest tree improvement. Atlanta, Georgia, January 9-10, 1951. Mimeographed. U. S. Forest Service, Atlanta, Georgia.

2. Proposal for a cooperative study of geographic sources of southern pine seed. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Mimeographed. Southern Forest Experiment Station, New Orleans, Louisiana. October 25, 1951.

3. Standardized working plan for local tests of seed source. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Mimeographed. Southern Forest Experiment Station, New Orleans, Louisiana. October 24, 1951.

4. Hereditary variation as the basis for selecting superior forest trees. Subcommittee on Tree Selection and Breeding, Keith W. Dorman, Chairman. Southeastern Forest Experiment Station, Station Paper No. 15. March 1952.

5. Directory of forest genetic activities in the South. Subcommittee on Tree Selection and Breeding, Keith W. Dorman, Chairman. Southeastern Forest Experiment Station. Station Paper No. 17. July 1952.

6. Working plan for cooperative study of geographic sources of southern pine seed. Subcommittee on Geographic Sources of Seed, Philip C. Wakeley, Chairman. Processed, Southern Forest Experiment Station, New Orleans, Louisiana. September 12, 1952.

7. Suggested projects in genetic improvement of southern forest trees. Committee on Southern Forest Tree Improvement, Southeastern Forest Experiment Station, Station Paper No. 20. December 1952.

8. Testing tree progeny. A guide prepared by the Subcommittee on Progeny Testing, E. G. Wiesehuegel, Chairman. Processed, Tennessee Valley Authority. Technical Note No. 14. December 1952.

9. Report of the second southern conference on forest tree improvement. Atlanta, Georgia, January 6-7, 1953. Mimeographed. U. S. Forest Service, Atlanta, Georgia.

10. Progress in study of pine races. Philip C. Wakeley. Southern Lumberman 187 (2345): 137-140. December 15, 1953.

11. The role of genetics in southern forest management. By a special Sub-Committee of the Committee on Southern Forest Tree Improvement, Bruce Zobel, Chairman. 3 parts. Forest Farmer 14 (1): 4-6, 14-15. Forest Farmer 14 (2): 8, 14-19. Forest Farmer 14 (3): 8-9, 14-15. (Reprint, 11 pp. 1954.)